

AF-GEOSPACE USER'S MANUAL VERSION 1.4 AND VERSION 1.4P

Robert V. Hilmer, Editor

30 September 1999

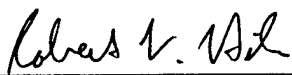
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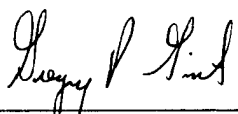
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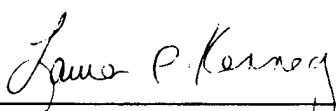
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13. ABSTRACT (Maximum 200 words) The Air Force Research Laboratory master program AF-GEOSpace (Versions 1.4 and 1.4P) provides a user-friendly graphical interface to a variety of scientific models constructed to facilitate the assessment of natural hazards in the near-Earth space environment. Environmental effects range from navigation and communication link outages caused by ionospheric scintillation to satellite system failures caused by intense magnetospheric particle fluxes. Included are models of low-Earth orbit radiation dosages, radiation belt electron and proton flux derived from CRRES satellite data, auroral precipitation based on DMSP data, the ionosphere and its scintillation effects, cosmic rays and the solar proton environment, interplanetary shock propagation, and satellite Single Event Effects probabilities. Common input data sets, applications modules (e.g., orbit propagators), and graphical visualization tools are provided to all of the models. Results from multiple models can be displayed in 1-D line plots, 2-D contours or coordinate slices, and 3-D isocontours. Applications modules provide estimates of linear energy transfer and single event upset rates in solid state devices, HF ray tracing capabilities, and the visualization of geomagnetic field lines, radar fans, communications domes/links, and satellite detector cones. Data modules display DMSP auroral particle data and qualitatively specify enhanced outer zone MeV electron intensities.				
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WELCOME TO AF-GEOSpace

AF-GEOSpace is a user-friendly, graphics-intensive master program bringing together many of the space environment models and applications developed over the last 50 years by the Battle-space Environment Division of the Air Force Research Laboratory (formerly the Geophysics Directorate of the USAF Phillips Laboratory, the Air Force Geophysics Laboratory, and the Air Force Cambridge Research Laboratories), its contractors, and collaborators. AF-GEOSpace provides operators, engineers, forecasters, scientists, students, and teachers with tools to accomplish a wide variety of tasks including:

- Optimal orbit specification for avoidance of radiation hazards
- Satellite design assessment and post-event analysis
- Forecasting of solar disturbance effects
- Frequency and antenna management for radar and HF communications
- Determination of communication link outage regions for active ionospheric conditions
- Near real-time display of satellite space environment sensor data
- Interplanetary, magnetospheric, and ionospheric physics research and education

AF-GEOSpace Version 1.4 contains gridded models of the ionosphere, aurora, radiation belts, the cosmic rays and solar protons penetrating the geomagnetic field, and the geomagnetic field itself. Feature and effects models are provided for ionospheric scintillation, solar proton events, and interplanetary shocks. Application tools include HF ionospheric ray tracing, orbit generation, integration of radiation belt fluxes and doses along orbits, display of detector cones, communication links and radar fans, and worksheets for transforming coordinates and time. Graphical user interfaces and a host of one-, two-, and three-dimensional output visualization tools support the models and applications. AF-GEOSpace was designed to be extremely versatile in the ways its model displays can be sliced, divided, combined, and tied to different applications and coordinate systems.

Several real-time data functions and applications in Version 1.4 have been developed specifically for use by the USAF 55th Space Weather Squadron (55SWXS). These include the *Latest* and *Recent* Global Parameter updates, automatic generation of orbit ephemeris files, and the High Energy Electron Monitor (HEEM) and DMSP_SPECTRA Data Modules. To illustrate the functionality of these modules sample data files are included in the CDROM release. At 55SWXS these files are generated in real-time from scripts accessing the 55SWXS data bases. In addition, scripts have been included that can be used to automatically download the global parameters from the NOAA Space Environment Center.

An important part of this User's Manual are the examples found in the final section. Click-by-click instructions are given for using AF-GEOSpace to investigate several solar, magnetospheric, and ionospheric phenomena that have well known effects on communications and spacecraft systems. Mastering all of the examples will teach the user much of AF-GEOSpace's capability.

The AF-GEOSpace development team always appreciates comments, bug reports, and suggestions for future development. Send messages via e-mail to *Robert.Hilmer@Hanscom.af.mil*.

A Note on Software Versions

This User's Manual, approved for unlimited public distribution, describes two AF-GEOSpace software application packages released concurrently by the Air Force Research Laboratory, namely, Version 1.4 and Version 1.4P.

AF-GEOSpace software was developed by the US Air Force and should not be redistributed or copied in whole or in part for sale. The USAF and the Air Force Research Laboratory are not liable for any damages resulting from the use of the information contained in this document or the computer software it describes.

Version 1.4 software includes the complete inventory of Science and Application Modules listed in the table of contents of this User's Manual and is generally distributed only to pre-approved government institutions and their agents. Members of the general public who wish to obtain this version of the software should contact the AF-GEOSpace development team to initiate the necessary release approval procedure.

Version 1.4P software, approved for unlimited public distribution, is identical to the Version 1.4 software except for the absence of four Science Modules (i.e., ISPM, PPS, STOA, and WBMOD) and one Application Module (i.e., WBPROD-APP). Members of the general public interested in obtaining the aforementioned modules, i.e., the Version 1.4 software package, should see the note above.

Installing AF-GEOSpace

AF-GEOSpace is distributed on CD-ROM as a series of UNIX tar files and an install script. A Silicon Graphics workstation is required running IRIX 5.2 or greater. While the hard disk space required depends on the models installed and the spatial resolution set by the user at run-time, about 300-350 MB is recommended.

To install AF-GEOSpace:

1. Insert the CD-ROM.
2. Mount the CD-ROM following the instructions of your local site guide. In the following discussion, the mount point of the CD-ROM will be referred to as `$CD_HOME`. When implementing the commands in the following procedures, change the variable `$CD_HOME` to refer to the mount point of your CD-ROM (usually `$CD_HOME = /CDROM`).
3. Choose or create an installation directory. All AF-GEOSpace files will be installed in subdirectories of the installation directory. In the following discussion, the installation directory will be referred to as `$AFGS_HOME`. When implementing the commands in the following procedures, change the variable `$AFGS_HOME` to refer to your chosen installation directory (e.g., `$AFGS_HOME = /usr/people/yourname/geospace`).
4. Change into the installation directory, e.g.,

```
cd $AFGS_HOME
```

5. Start the installation script by issuing the following command at the UNIX prompt:

```
$CD_HOME/install.af
```

6. The install script will start with a short message about its purpose and then ask if you wish to continue with the procedure. If you do wish to continue, answer 'y'.
7. You will next be asked if you will be installing software. If you do want to install software from the CD (as opposed to just removing software), answer 'y'.
8. If you answered that you will be installing software, you will be asked to provide the distribution directory containing the tar files. This should be on the CD-ROM under the 'tars' subdirectory. Hence, the distribution directory is \$CD_HOME/tars. Type this directory name in response to the question (substituting the appropriate path name for \$CD_HOME).
9. At this point, the installation script will present you with a series of options. If you are installing software, you can install everything, remove all the AF-GEOSpace software, install/remove only portions of the AF-GEOSpace software, or quit the installation script. Answer the question accordingly.
10. Depending on the option you select, the installation script will install/remove the software or ask you further questions about which portions of the software to install/remove. Answer the questions according to your local needs. The AF-GEOSpace Base Software and AF-GEOSpace Models Base Software portions of AF-GEOSpace must be installed for minimal functionality. Other models may be installed as desired.
11. At the end of the installation, you may be asked if you want to append your .login file with environment variable definitions and an alias required to run AF-GEOSpace (see Setting-Up AF-GEOSpace below). If you will be a frequent user of AF-GEOSpace, answer 'y' to the question to automatically set-up your account for running AF-GEOSpace. If you answer 'y', the command 'AFGS' will run AF-GEOSpace.
12. As a final optional step to the installation, you may want to install the AF-GEOSpace icon file. To do this, you will need superuser privileges. Issue the following command at a UNIX prompt:

```
cp AF-GEOSpace.icon /usr/lib/images
```

Setting-Up AF-GEOSpace

Before using AF-GEOSpace, users will need to set some environment variables and an alias. This can be done in several ways:

1. Set the environment variables to define where AF-GEOSpace is located and define an alias to the AF-GEOSpace command. This can be done manually by issuing the following commands

(remember to substitute the appropriate directory for \$AFGS_HOME in the following):

```
setenv LD_LIBRARY_PATH      $AFGS_HOME/PLGS/lib
setenv PLGS_MODELS          $AFGS_HOME
setenv XUSERFILESEARCHPATH  $AFGS_HOME/%N
alias AFGS                   $PLGS_MODELS/PLGS/bin/AF-GEOSpace
```

2. Alternatively, a script is provided to simplify this set-up. To set the variables and alias correctly using the script, issue the following commands:

```
cd $AFGS_HOME
source AFGS.Setup
```

3. Finally, if a user will be using AF-GEOSpace frequently, the script may also be used to add the commands to the .login file (so they don't have to be repeated on each subsequent log in). To do this, issue the following commands:

```
cd $AFGS_HOME
cp $HOME/.login $HOME/.login.bak
source AFGS.Setup | cat $HOME/.login.bak - > $HOME/.login
```

Running AF-GEOSpace

After completing the Set-up as described above, AF-GEOSpace may be run by issuing the 'AFGS' command. It is suggested that AF-GEOSpace be run in a working directory since it will generate a variety of temporary files. Hence, an example of a AF-GEOSpace session might be as follows:

```
mkdir my_work_dir
cd my_work_dir
AFGS
```

Removing AF-GEOSpace

The install.af script will copy itself to \$AFGS_HOME/install.af. This script can be used to remove software with or without the original CD. Use the following procedure to remove AF-GEOSpace software using the install.af script:

1. Issue the following commands to run the install.af script:

```
cd $AFGS_HOME
install.af
```

2. Answer 'y' when asked if you want to continue.

3. Answer 'n' when asked if you want to install software.
4. When presented with the list of options, answer 'R' to remove all the AF-GEOSpace software.
5. Choose 'Q' to quit the script when the removals are completed.
6. As a final step, if the icon image was installed, remove it by issuing the following command (this may require superuser privileges):

```
rm /usr/lib/images/AF-GEOSpace.icon
```

As an alternative to using `install.af` to remove the AF-GEOSpace software, the following will completely remove all AF-GEOSpace software **and all user files stored in the AF-GEOSpace installation directory**. Although effective, these commands should be used with **great care** (the last command removes optionally installed software and may require superuser privileges):

```
cd $AFGS_HOME
rm -r *
rm /usr/lib/images/AF-GEOSpace.icon
```

A Note on Swap Space

Depending on the number and size of models run through AF-GEOSpace, users may find the machine running out of virtual memory. This problem can be remedied by creating virtual swap space. The user should ask the system administrator to add virtual swap space to the machine's configuration. Administrators should check their local documentation. However, as an example of adding virtual swap space, the following procedure adds 100Mb virtual swap space to an SGI Indigo 2 running IRIX 6.2 or 6.3 (superuser privileges required):

1. Make a virtual swap file of 0 bytes size:

```
mkfile 0b /swap.virtual
```

2. Add the swap resource to the `/etc/fstab` file by adding the following line:

```
/swap.virtual swap swap pri=3,vlength=204800 0 0
```

3. Use the new swap space:

```
/sbin/swap -m
```


Getting Started

The first window displayed upon starting AF-GEOSpace is the Welcome Window displaying two Environment manager boxes and three buttons labeled *Help*, *Messages*, and *Quit*.

Available Environment Modules are shown in the left Environment manager box. Version 1.4 supports only the STATIC environment representation. Clicking the mouse on the *GEOSPACE: STATIC* label will add the environment to the list of *Active Environment Modules* and open an Environment window.

Active Environment Modules are shown in the right Environment manager box. This box lists Environment objects which have been created. Clicking on a label inside the *Active Environment Modules* list will bring the corresponding window to the top of all windows currently displayed on the screen.

The *Help* button brings up the Netscape browser to view the html version of this document.

The *Message* button opens the AF-GEOSpace messaging system that allows text messages to be stored and retrieved at later times by any user. Details of how to use the messaging system are given in the Miscellaneous Topics section of this User's Manual.

The *Quit* button terminates AF-GEOSpace, deleting all objects and graphics that have been created during the session.

After opening an Environment Module, the eager user can go right to the Examples section of this User's Manual to begin using AF-GEOSpace.

Environments

Environments, as defined by the Environment Modules, are top level objects in AF-GEOSpace. Currently, only one type of environment is supported, GEOSPACE: STATIC.

The Environment Module interfaces to science, applications, and graphic modules needed to investigate the solar, interplanetary, magnetospheric, auroral, and ionospheric environments and their effects on communications and spacecraft systems. Version 1.4 of AF-GEOSpace supports only the STATIC environment representation. That is, with the exception of satellite orbits and associated tools, all environment models and applications are run for a fixed Universal time and fixed set of geophysical parameters. When using AF-GEOSpace to do a comparative study of space environments for different geophysical conditions it is recommended that different Environment Modules be used for each case. Upon creation of a Near-Earth Space environment, an Environment window is displayed containing a menu bar and a section for specifying the global parameters.

Global Parameters

Global parameters are the date, time, and geophysical indices that are shared between many of the models. The purpose of the global parameters section is to help maintain consistent inputs to the plurality of models that can be created within a single Static Environment. Most models have additional parameter inputs that will be requested when initializing the appropriate module. The global parameters are:

Year:	year
Day:	day of year in the form DDD or MM/DD
Time:	Universal Time in the form HH:MM
Kp:	planetary magnetic activity index input in decimal form
SSN:	Sun spot number
F10.7:	the instantaneous solar radio flux at 10.7 cm (2800 MHz) input in units of $10^{22} W \cdot m^{-2} \cdot Hz^{-1}$
Ap:	planetary magnetic index in integer form

When an *Environment* Window is first created, the time and date are automatically loaded using values obtained from the host computer clock. The geophysical indices appear as the unphysical values '-1' until the user chooses the parameters in one of the menus described below.

The definitions of Kp, SSN, F10.7, and Ap are identical to those used for the geophysical index archives maintained by the National Geophysical Data Center (NGDC) in Boulder, Colorado. Values for these parameters can either be directly typed into the boxes by the user or automatically read in from either the archived or near real-time files as specified by the *Globals* button. These options for the global parameters files are given below.

Archive

When *Archive* is selected with the *Globals* button, the NGDC archived values of the geomagnetic indices valid for the *Year*, *Day*, and *Time* entered in the respective global parameter boxes are automatically loaded. AF-GEOSpace Version 1.4 contains the NGDC geophysical index archive files from Jan 1940 through Jan 1999 in the directory:

```
$PLGS_MODELS/MODELS/data/GLOBALS/KP
```

Each file in this directory is a year's worth of indices with the current year's file only partially full. The AF-GEOSpace convention is to label the file *kpNNNN*, where *NNNN* is the year. Thus the indices for 1991 are stored in the file *kp1991*.

It is straightforward to keep the archived data in AF-GEOSpace up-to-date by periodically downloading the most recent NGDC archived data files. The latest date in the NGDC archive files is typically 15-30 days behind the current date. An example showing how to update the AF-GEOSpace data base from the NGDC archive is given below using 1999 as the subject year.

```
cd $PLGS_MODELS/MODELS/data/GLOBALS/KP
ftp ftp.ngdc.noaa.gov
(log in using the username anonymous and your local e-mail address as a password)
```

```
ftp> cd /STP/GEOMAGNETIC_DATA/INDICES/KP_AP
ftp> get 1999.10
ftp> quit
mv 1999.10 kp1999
```

Recent

When *Recent* is selected with the *Globals* button, the values of the geomagnetic indices from the near-real time files (see *Latest* below) valid for the *Year*, *Day*, and *Time* entered in the respective global parameter boxes are automatically loaded. The data base of near real-time estimates can be used to run AF-GEOSpace for time-periods not yet covered by the NGDC archive.

Latest

When *Latest* is selected with the *Globals* button, the most recent time and global indices available for the *Year* entered in the global parameter box are automatically loaded from files in the directory,

\$PLGS_MODELS/MODELS/data/GLOBALS/RT

The files in this directory contain near real-time estimates of the indices as computed by the USAF 55SWXS and NOAA/SEC and are meant to be updated in near-real time. File naming conventions and formats are identical to the NGDC archive files, with the exception of a header line in each file giving the date and time of the most recent update. Note that the real-time parameter estimates for a given date often differ from the values that eventually appear in the NGDC archive files.

Real-Time Parameters at 55SWXS

For AF-GEOSpace at the 55SWXS, the current year's file is updated every 3 hours from the operational data bases. The source of each index is described below.

Index,	Database,	Entity-Set,	Attribute(s)
3-hr K _p ,	AP_DB,	GEOMAG_INDEX,	KP_03_RUN
F10.7,	AP_DB,	F10_MEAN_90_PREDICTION,	P_OBSERVED_20Z
SSN,	AP_DB,	SSN,	IACTIN
Ap,	AP_DB,	GEOMAG_INDEX,	AP_03_RUN

Current 3-hour K_p values are taken from the GEOMAG_INDEX table in the AP_DB database and are used as the most recent values in the file. Values for the two previous 3-hour intervals are also updated based upon data extracted from the same table. F10.7 values, measured at 2000 GMT in Penticton CA and valid for the next day, are available around 2045 GMT and are in the database update by midnight. The SSN value is an average of the number of sunspots seen by tele-

scopic observation for the latest date available, made by those observatories with the best quality seeing. Values for the Ap index are retrieved from the GEOMAG_INDEX table in the AP_DB. The date and time loaded into AF-GEOSpace corresponds to the latest three hour K_p.

Real-Time Parameters Over the Internet

Data from NOAA/SEC (Space Environment Center), containing selected geomagnetic and solar activity indices is available via anonymous FTP from ftp.sec.noaa.gov in the directory named pub/latest. A script that downloads this data automatically on a daily basis can be executed via the standard cron daemon. The expect script *ftp-sgas* intended for this purpose is provided in the directory \$AFGS_HOME/PLGS/sec_script. To implement this script on a standard Unix system, add a line similar to the following to a crontab file:

```
0 23 * * * /data/RT_DATA/GLOBALS/SEC/ftp-sgas
```

The example above initiates the execution of the script *ftp-sgas* every night at 23:00.

In order to run the script, the expect shell must be present on the system. It can be obtained from <http://expect.nist.gov>. Two lines in the script should be modified to reflect the location of specific files on the system. The first line should indicate the location of the expect shell on the system. The line “cd /data/RT_DATA/GLOBALS/SEC” should indicate the location in which the downloaded data is to be placed as the argument to the cd command. This should also be the location of the script *ftp-sgas* and the processing program *addsgasfile* (also provided in the directory \$AFGS_HOME/PLGS/sec_script).

The script downloads the file *SGAS.txt*, renaming it to *SGASmmddyyyy.txt*, where *mm*, *dd*, and *yyyy* are the month, day, and year. The script subsequently calls the program *addsgasfile* which processes the data and appends it to the file *kpyyyy* in the format described in the file *kp_ap.doc* (which is the format required by AF-GEOSpace).

To facilitate the use of SEC data with AF-GEOSpace, the environment variable PLGS_GLOBALS_RT_DATADIR should be set to the directory containing the downloaded data from SEC, e.g.,

```
setenv PLGS_GLOBALS_RT_DATADIR /data/RT_DATA/GLOBALS/SEC
```

Environment Menus

The menu bar at the top of each environment provides access to functions which manage science, application, and graphics modules, create graphics windows, and access help. This section will describe each of the menu choices in turn.

- **Administration:** The *Admin* menu button accesses the administration pulldown menu.
 - Save as:** The *Save as* function saves the entire set of model and visualization parameters used in the current AF-GEOSpace session. The session may be saved as a specially formatted script file or into a series of network Common Data Format (netCDF) files. The AF-GEOSpace *Script File* option creates a script file containing the parameters and commands needed to re-construct the current session and is relatively small in size. Using the *netCDF File* option saves the parameters, commands, and data sets in netCDF format. These can be quite large, depending upon the models run.
 - Load as:** The *Load as* function allows the user to read-in either the specially formatted AF-GEOSpace script files or netCDF files created with the *Save as* function during a previous session. Note that the script files will run the models again.
 - Delete:** This function is accessed by choosing the *Delete* button under the administration pulldown menu. The *Delete* function will destroy the current environment, including all associated models and graphics. All information from the environment is lost when the *Delete* function is activated.
- **Modules:** The *Modules* menu button accesses the modules pulldown menu. The modules pulldown menu provides access to Science, Application, Data, Graphics, and Worksheet modules. Most of the functionality of AF-GEOSpace is accessed via this menu.
 - Science Modules:** The *Science* option under the modules pulldown menu provides access to the science manager. Once activated, lists of Available and Active Science modules are visible. Science Modules may be managed by making appropriate choices from these lists.
 - Application Modules:** The *Applications* option under the modules pulldown menu provides access to the application manager. Once activated, lists of Available and Active Application modules are visible. Applications may be managed by making appropriate choices from these lists.
 - Data Modules:** The *Data* option under the modules pulldown menu provides access to the data module manager. Once activated, lists of Available and Active Data modules are visible. Applications may be managed by making appropriate choices from these lists.
 - Graphics Modules:** The *Graphics* option under the modules pulldown menu provides access to the graphics module manager. Once activated, lists of Available and Active Graphics modules are visible. Applications may be managed by making appropriate choices from these lists.
 - Worksheet Modules:** The *Worksheet* option under the modules pulldown menu provides access to the worksheets manager. Once activated, lists of Available and Active Worksheet modules are visible. Applications may be managed by making appropriate choices from these lists.

- **Windows:** The *Windows* menu button accesses the windows pulldown menu. The windows pulldown menu provides access to functions for creating graphics windows.
 - Create 1D Plot:** Activating the *Create 1D Plot* option will create a new plot window. The 1D plot windows are designed for displaying line plots of data created by science, application, or data modules.
 - Create 2D Plot:** Activating the *Create 2D Plot* option will create a new plot window. The 2D plot windows are designed for projection of data created by science, application, or data modules onto a 2D surface (currently the Earth's surface).
 - Create 3D Plot:** Activating the *Create 3D Plot* option will create a new plot window. The 3D plot windows are designed for display of 3D data created by science, application, or data modules.
 - Animation:** Selecting *Animation* will allow the user to animate orbits and data sets in the Plot1D, Plot2D, and Plot3D windows.
- **Help:** The *Help* menu activates the Netscape browser for viewing an html version of the AF-GEOSpace User's Manual.

Science Modules

Science modules provide methods for generating data sets from various models of the space environment. The science modules are accessed through the science module manager which becomes visible when the *Science* button under the Environment's window *Modules* pulldown menu is activated. The science module manager consists of two lists - *Available Science Modules* and *Active Science Modules*. *Available Science Modules* are all the modules currently supported by AF-GEOSpace. *Active Science Modules* are modules which have been created and used by the AF-GEOSpace user during the current session.

When initially accessed, the science module manager will show a list of science modules under *Available Science Modules*. Since no science modules have yet been created, the *Active Science Modules* list will be empty.

Currently, the following science modules are supported by AF-GEOSpace:

- **APEXRAD:** The APEXRAD space radiation dose model specifies the location and intensity of the radiation dose rate behind four different thicknesses of aluminum shielding for five geomagnetic activity levels as specified by Ap15. It covers the Low Earth Orbit (LEO) altitude region (360-2400 km) and was developed to supplement the CRRESRAD model (see below) which has limited resolution in the LEO regime.
- **AURORA:** The auroral precipitation model specifies the location and intensity of electron number and energy flux, ion number and energy flux, Pederson and Hall conductivities, and the equatorward boundary at 110 km altitude. This module also provides the capability to map flux, conductivity, and equatorial boundary values up magnetic field lines into the three-dimensional magnetospheric grid.
- **CHIME:** The CRRES/SPACERAD Heavy Ion Model of the Environment (CHIME) specifies the location and intensity of galactic cosmic rays and/or solar energetic particle fluxes and/or anomalous cosmic ray fluxes.
- **CRRESELE:** The Combined Radiation and Release Effects Satellite (CRRES) electron flux model specifies the location and intensity of electron omnidirectional flux over the energy range 0.5-6.6 MeV for a range of geomagnetic activity levels.
- **CRRESPRO:** The Combined Radiation and Release Effects Satellite (CRRES) proton flux model specifies the location and intensity of proton omnidirectional flux over the energy range 1-100 MeV for quiet, average, or active geophysical conditions.
- **CRRESRAD:** The Combined Radiation and Release Effects Satellite (CRRES) space radiation dose model specifies the location and intensity of the radiation dose rate behind four different thicknesses of aluminum shielding for active or quiet geophysical activity levels.
- **ISPM:** The Interplanetary Shock Propagation Model predicts the transit time of interplanetary shocks from the sun to the Earth and the shock strength upon arrival.

- **NASAELE:** The NASA AE-8 radiation belt models are used to compute the intensity and location of differential omnidirectional electron flux for ten energy intervals between 0.5 and 6.6 MeV which correspond to the ranges of the CRRES HEEF instrument.
- **NASAPRO:** The NASA AP-8 radiation belt models are used to compute the intensity and location of differential omnidirectional proton flux for 22 energy intervals between 1 and 100 MeV which correspond to the ranges of the CRRES PROTEL instrument.
- **PIM (Parameterized Ionospheric Model):** A global ionosphere model generating electron number density as well as maps of total electron content (TEC), Height of E and F2 peaks (H_E, H_{F2}), and plasma frequencies at the E and F2 peaks (F_oE, F_oF₂) as a function of a variety of geophysical activity indices.
- **PPS (Proton Prediction System):** Provides forecasts of the intensity and duration of solar proton events.
- **SEEMAPS:** Normalized flux and dose data for protons with energy > 50 MeV from the APEX and CRRES satellites are used to produce contour maps of relative probabilities of experiencing Single Event Effects (SEEs) in the Earth's inner radiation belts.
- **STOA (Shock Time-of-Arrival Model):** Predicts the transit time of interplanetary shocks from the sun to the Earth. STOA is a predecessor of ISPM.
- **WBMOD (WideBand Model):** An RF ionospheric scintillation model specifying S₄, S_i, and other scintillation parameters between any location on the globe and a satellite above 100 km altitude at any frequency above 100 MHz as a function of a variety of geophysical activity indices.

Running Science Modules

To run a *Science* module, click the mouse on the desired choice under the *Available Science Modules*. For example, to create a new version of the CRRESELE, click the mouse on *CRRESELE* in the *Available Science Modules* list. Choosing a science module will do two things: first, the choice is added to the *Active Science Modules* list; second, the options associated with the chosen science module will appear below the science module manager windows. In general, each science module will have a different Environment Window representing the module specific inputs.

The bottom section of the science module window is the same for all science modules. It consists of a status window and buttons for running and deleting the science module, a button to access the grid tool, and a button to allow the science data to be saved to a file.

- **Model Status:** The *Model Status* box provides a brief informational message regarding the current state of the science module. Upon creation, the status will be "MODEL INITIALIZED". If the science module is up-to-date and ready for use by other modules, the message will indicate "MODEL IS READY AND UP TO DATE". If parameters have been changed since last running the science module, the status box will indicate "PARAMETERS MAY HAVE CHANGED". Other informational messages may also be displayed depending on the specific science module. A scroll feature is provided for reading longer messages.
- **Run Model:** After setting all of the inputs as desired, the science module may be executed by activating the *Run Model* button. An informational box will appear indicating the science module is running. When completed, the informational box will disappear. At this point, the data generated by the science module is available for use by graphics modules.
- **Delete Model:** If the science module is no longer needed, it may be deleted by selecting the *Delete Model* button.
- **Grid Tool:** Most science modules calculate data on a grid and *Grid Tool* allows the user to choose the parameters associated with the calculation grid. Activating the *Grid Tool* button will open the *Grid Tool* window. More information on the *Grid Tool* can be found in the Miscellaneous Topics section of this manual.
- **Save To File:** Data from the science module may be stored to disk in several formats. Activating the *Save To File* button opens a window allowing options on formats and variable choices to be set. More information on the *Save to File* options are given in the Miscellaneous Topics section of this manual. The capability to generate ASCII files of user-specified one-dimensional slices of science module data is provided by the COORD-PROBE graphics module.

The APEXRAD Science Module

Model Name: APEXRAD

Version: 15 September 1997

Developer: Air Force Research Laboratory

References: Bell, J.T., and M.S. Gussenhoven, APEXRAD Documentation, *PL-TR-97-2117* (1997), ADA 331633

Gussenhoven, M.S., E.G. Mullen, D.A. Hardy, D. Madden, E. Holeman, D. Delorey, and F. Hanser, Low Altitude Edge of the Inner Radiation Belt: Dose Models from the APEX Satellite, *IEEE Trans. Nucl. Sci.*, **42**, 2035 (1995)

Gussenhoven, M.S., E.G. Mullen, J.T. Bell, D. Madden, and E. Holeman, APEXRAD: Low Altitude Orbit Dose as a Function of Inclination, Magnetic Activity and Solar Cycle, *IEEE Trans. Nucl. Sci.*, **44**, 2161 (1997)

Mullen, E.G., M.S. Gussenhoven, J.T. Bell, D. Madden, E. Holeman, and D. Delorey, Low Altitude Dose Measurements from APEX, CRRES, and DMSP, *Advances in Space Res.*, **21**, 1651 (1997)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

APEXRAD Overview

The APEXRAD module is a UNIX port of the PC program APEXRAD developed and released by the Air Force Research Laboratory. APEXRAD has been produced to supplement the higher altitude CRRESRAD dose models. The following description of APEXRAD is excerpted from the APEXRAD Documentation:

“APEXRAD uses empirical models based on data from the APEX/PASP+ dosimeter to predict the amount of radiation received in a user specified orbit behind four different aluminum shielding thicknesses. The Advanced Photovoltaic and Electronics Experiments (APEX) Satellite was operational from 3 Aug 94 to 2 Jun 96, just prior to solar minimum. APEX was in an elliptical orbit with a 70° inclination, a perigee of 362 km and an apogee of 2544 km. The instrument used to measure accumulated dose was the APEX Space Radiation Dosimeter which measures both dose rate and accumulated dose in four silicon detectors, each of which is behind an aluminum shield of a different thickness (Gussenhoven et al, 1995; Gussenhoven et al., 1997; Mullen et al., 1997). One shield was a 4.28 mil thick slab of Al. The other three were hemispheres of Al with thicknesses of 80.1, 225.8 and 444.4 mils. [...] The minimum energies required for particles to penetrate the shields and accumulate dose in the silicon detectors underneath are 0.15, 1, 2.5, and 5 MeV [respectively] for electrons and 5, 20, 35, and 50 MeV for protons [respectively] (Hanser and Morel, PL-TR-96-2088, ADA 311336, 1996). Dose from particles depositing 0.05-1 MeV and 1-10 MeV is accumulated in two different channels called LOLET and HILET respectively. Contributions to HILET dose are primarily from protons with energies of 5-125 MeV, but electrons with energies >5 MeV may contribute during large elec-

tron enhancement periods. Contributions to LOLET dose are from electrons, bremsstrahlung, and protons with energies $>80\text{MeV}$. Dosimeter data are available for approximately 14 of the 22 months that APEX was operational.”

The APEXRAD science module is used to map the radiation dose rate models from the APEX mission into a three-dimensional grid specified by the user. A variety of magnetic field models can be used for the mapping. Six dose rate models were derived from the APEX data as described by the following excerpt from the APEXRAD User’s Manual:

“The dose models used by APEXRAD are based on in-situ dose rate measurements made on board the APEX satellite [as described in the excerpt above]. The delta dose measured by the dosimeter over the 24-second intervals was used to build the APEXRAD models. A background subtraction is performed to remove the dose due to constant sources, which include both the on-board alpha source used for calibration, and cosmic rays (Gussenhoven et al 1997). The measured dose rates for each dome were binned by L and B/B_0 to make average dose rate models in rads (Si) per second. The width of each bin in L is $1/100$ RE, and the width of each bin in B/B_0 is one degree of $\arcsin(B/B_0)-1/2$ (approximately 0.75° latitude in a dipole field). The bins form a two-dimensional array of 500 (L) by 90 (B/B_0) and over L values of 1 to 6 RE and magnetic latitudes of 0° to $\sim 60^\circ$. Many of these bins do not contain data because APEX was in a low altitude orbit and only reached high L values at high B/B_0 ’s. To save storage space most of the empty data bins are not stored as part of the models.

Six sets of APEXRAD models were produced. The first set of models is the entire mission average. The other five sets of models are based on the Earth’s magnetic activity as recorded by A_p15 , a fifteen day running average of the A_p index. The location and intensity of the outer belt horns is dependent on the magnetic activity. Higher activity levels coincide with a significant increase in the LOLET dose rate (up to a factor of 10) where the horns of the outer belt come down to low altitudes. The position of the horns also change with magnetic activity. The HILET dose rate in portions of the inner belt is found to decrease slightly as the magnetic activity increases, however, this decrease is small (less than 20 percent from one activity level to the next) and restricted to the inner edge of the belt. Thus varying magnetic activity has negligible effect on the HILET dose predictions for most orbits. The cumulative effect of varying magnetic activity on total dose received will depend on the orbit. For orbits that pass through the heart of the inner belt[, the] dose from inner belt protons will dominate the total dose and magnetic activity will have little impact. For a certain class of low altitude, high inclination orbits, increases in magnetic activity can lead to a significant increase in total dose rate.”

After the user selects which data model is desired, the APEXRAD science module calculates the B/L coordinates of each grid point from the user-specified magnetic field model. The resulting dose rate is then obtained from the B/L coordinates and the chosen data model. That dose rate is assigned to the grid point. In this manner a fully three-dimensional map of the dose rate data may be made from the APEX data.

Warning: Although AF-GEOSpace allows the data to be mapped in three dimensions using a variety of magnetic field models, the original APEX data was binned into B/L coordinates using the IGRF95 magnetic field model. The user should be aware that using other magnetic field mod-

els to map the data into three dimensional space is inconsistent with the original data reduction.

APEXRAD Inputs

The APEXRAD science module requires the user to specify the combination of dosimeter particle energy ranges and aluminum shielding thickness as well as the magnetic activity level and the magnetic field model used in mapping the data.

The APEXRAD options are,

B-Model:	The magnetic field model is used to convert from the B-L coordinates of the model to three-dimensional space. The default is the field model used to reduce the APEX data set: IGRF95. The complete options are: Dipole: A dipole field Dipole-Tilt: A tilted dipole field Dip-Tilt-Off: A tilted-offset dipole field IGRF95: The International Geomagnetic Reference Field (1995) with no external contributions. IGRF95/O-P: The <i>IGRF95</i> internal field with the <i>Olson and Pfitzer</i> (1977) static model to represent the external field.
Shielding:	The shielding parameter specifies whether the 4.29, 82.5, 232.5, or 457.5 mil Al hemisphere shielding thickness data set is to be used.
Channel:	The channel parameter specifies which dose rate data set is to be used: Lo Let: (0.05 - 1 MeV) Hi Let: (1 - 10 MeV) Total: = <i>Lo Let</i> + <i>Hi Let</i>
Activity:	This parameter specifies which of the five flux model sets corresponding to the five geomagnetic activity levels as specified by Ap15 is to be considered, i.e., 5.0 - 7.5, 7.5 - 10, 10 - 15, 15 - 20, or 20 - 25. Also possible is the choice of the mission average (<i>Whole Mission</i>) model set.

APEXRAD Outputs

The APEXRAD science module returns a 3D Gridded Data Set of the dose rate in units of Rads Si/s for the selected shielding level, detector, and activity combination.

The AURORA Science Module

Model Name:	Aurora
Version:	September 1998
Developer:	Air Force Research Laboratory
References:	<p>Brautigam, D.H., M.S. Gussenhoven, and D.A. Hardy, A Statistical Study on the Effects of IMF Bz and Solar Wind Speed on Auroral Ion and Electron Precipitation, <i>J. Geophys. Res.</i>, 96, 5525-5538 (1991)</p> <p>Hardy, D.A., W. McNeil, M.S. Gussenhoven, and D. Brautigam, A Statistical Model of Auroral Ion Precipitation 2. Functional Representation of the Average Patterns, <i>J. Geophys. Res.</i>, 96, 5539-5547 (1991)</p> <p>Madden, D., and M.S. Gussenhoven, Auroral Boundary Index from 1983 to 1990, <i>GL-TR-90-0358</i>, Phillips Laboratory, Hanscom AFB, MA (1990)</p> <p>Hardy, D. A., M.S. Gussenhoven, and D. Brautigam, A Statistical Model of Auroral Ion Precipitation, <i>J. Geophys. Res.</i>, 94, 370-392 (1989)</p> <p>Hardy, D. A., M.S. Gussenhoven, R.A. Raistrick, and W. McNeil, Statistical and Functional Representations of the Pattern of Auroral Energy Flux, Number Flux, and Conductivity, <i>J. Geophys. Res.</i>, 92, 12275-12294 (1987)</p> <p>Hardy, D. A., M.S. Gussenhoven, and E. Holeman, A Statistical Model of Auroral Electron Precipitation, <i>J. Geophys. Res.</i>, 90, 4229-4248 (1985)</p> <p>Gussenhoven, M.S., D.A. Hardy, and N. Heinemann, Systematics of the Equatorward Diffuse Auroral Boundary, <i>J. Geophys. Res.</i>, 88, 5692-5708 (1983)</p> <p>Gussenhoven, M.S., D.A. Hardy, and W.J. Burke, DMSP/F2 Electron Observations of Equatorward Auroral Boundaries and their Relationship to Magnetospheric Electric Fields, <i>J. Geophys. Res.</i>, 86, 768-778 (1981)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

AURORA Overview

The AURORA science module accesses the set of Air Force Statistical Auroral Models (AFSAM), a compilation of time averaged auroral ion and electron models. These models were derived from precipitating particle measurements made by the SSJ/4 electrostatic analyzers flown on the F6 and F7 satellites of the Defense Meteorological Satellite Program (DMSP). The SSJ/4 analyzers determined the electron and ion spectrum in the local satellite zenith direction once per second over 20 channels spanning the energy range from 30 eV to 30 keV.

Statistical hemispheric particle precipitation maps were created for a range of different magnetospheric activity levels using the same spatial grid defined in corrected geomagnetic latitude (CGL) and magnetic local time (MLT). The high-latitude region grid was defined by 30 zones in CGL between 50° and 90° and 48 half-hour zones in MLT. The latitude zones were 2° wide between 50° and 60° and 1° wide between 60° and 80° latitude.

For a given level of activity, one-second spectra were accumulated in the CGL x MLT spatial grid defined above. For each spatial element, the average value of precipitating particle flux (electrons or ions) in each of the energy channels were then determined, and the resulting average spectra extrapolated to 100 keV. The large size of the DMSP data set ensured that a reasonable number of individual 1-s spectra occurred in each spatial element traversed by the satellite such that a statistically meaningful average spectrum could be determined. From these final differential number flux spectra, a number of key parameters were derived, including integral number flux, integral energy flux, average energy (ratio of integral energy flux to integral number flux), and the height-integrated Hall and Pedersen conductivities. To calculate the conductivities, we used the functional relations of *Spiro et al.* [*J. Geophys. Res.*, 87, 8215, 1982] as corrected by *Robinson et al.* [*J. Geophys. Res.*, 92, 2565, 1987].

The AFSAM models are separated according to (1) the magnetic activity index Kp and (2) the z-component of the interplanetary magnetic field (IMF Bz) in combination with the solar wind speed (Vsw). For the Kp model, there are 7 maps separated by whole values of Kp, i.e., one determination for Kp = 0, 0+, one for Kp = 1-, 1, 1+, etc., up to Kp = 5-, 5, 5+. One final separation is made for all cases with Kp ≥ 6-. For the Bz/Vsw model, there are 30 maps defined by the paired combinations of the 6 Bz values (-4.5, -2.2, -0.7, 0.7, 2.2, 4.5 nT) and the 5 Vsw values (346, 408, 485, 572, and 677 km/s).

The original Kp electron model [*Hardy et al.*, 1985] was constructed using data from the older SSJ/3 spectrometers flown on the DMSP F2 satellite and the P78-1 satellite. This model was followed by the Kp ion model [*Hardy et al.*, 1989] which was constructed using data from the newer SSJ/4 spectrometers flown on DMSP F6 and F7 satellites. For consistency, the original Kp electron model has been updated by a newer model (identical format) constructed from the same F6/F7 database which was used for the Kp ion model. The most recent AFSAM models are the Bz/Vsw models for both electrons and ions [*Brautigam et al.*, 1991].

AF-GEOSpace uses analytic representations of the key parameters derived from the average spectra and noted above. At this point, the reference for the analytical fits to the most current models has not yet been published in its complete form. However, the original reference for the Kp ion model fits to integral number flux and integral energy flux [*Hardy et al.*, 1991] remains valid. A publication referencing the complete set of AFSAM model fits is forthcoming.

The output domain of the AFSAM models is a two-dimensional (MLT, CGL) grid located at 110 km altitude (1.017 Earth radii). The default output grid in AF-GEOSpace is the AFSAM two-dimensional grid mapped to three-dimensional geocentric coordinates (GEOC) at an altitude of 110 km and at the time and activity level specified by the Global Parameter Kp or Bz/Vsw. Though the nominal altitude of the DMSP satellites is 840 km, the measured fluxes were mapped down the magnetic field lines to 110 km (the base of the ionospheric E layer) before constructing the AFSAM models.

The AF-GEOSpace AURORA science module extends the AFSAM models by providing the capability to map into three dimensions the magnetic field lines that intersect constant flux or conductivity contours on the two-dimensional model grid. This is done as follows: for each grid point in the user-specified three-dimensional grid, the unique magnetic field line intersecting this point is traced down to the original two-dimensional model domain at 110 km using a user-specified magnetic field model. The grid point is then given the flux (integral number or integral energy flux), average energy, or conductivity value existing at the point of intersection between the field

line and the original model domain at 110 km. By using the ISOCONTOUR or COORD-SLICE graphics objects on the resultant 3D AURORA dataset, magnetic field lines surfaces intersecting contours of constant flux in the original model domain can be easily visualized.

Note: The value of the flux, average energy, or conductivity specified by AF-GEOSpace at any altitude other than 110 km is NOT necessarily a meaningful value for that quantity. AF-GEOSpace uses the flux values on the three-dimensional grid above 110 km to denote sets of field lines emanating from the respective flux value isocontours at 110 km. The actual physical processes involved in determining the variation of flux values along the magnetic field lines have not been considered.

Also contained in the AURORA science module is an algorithm to determine the equatorward boundary of the aurora at 110 km altitude and map it along field lines generated by a user-specified magnetic field model. The algorithm represents a linear fit between the equatorward boundary (in the CGL coordinate) of the electron integral number flux and the Kp index for 24 sectors in MLT [Gussenhoven *et al.*, 1981; Gussenhoven *et al.*, 1983]. AF-GEOSpace uses the coefficients determined from over 200,000 DMSP boundary crossings in the interval 1983-1990 [Madden and Gussenhoven 1990]. Options are given to either (a) input Kp and output the entire equatorward edge boundary or (b) input a single observation of the equatorward edge in CGL and MLT (e.g., from one DMSP satellite crossing) and output the entire equatorward edge boundary. In the latter case, an “effective Kp” is computed by inverting the linear regression relation for the measurement in the single MLT bin and then using the effective Kp to calculate the equatorward edge in the remaining MLT bins.

AURORA Inputs

The Aurora science module requires the Global Parameters: Year, Day, UT, and Kp.

Note: When a 3-D grid is chosen, additional magnetic field model inputs necessary for magnetic field line mapping are required to be specified in the *Internal Field* and *External Field* sections outlined below. Additional information and references on the magnetic field models can be found in the BFIELD-APP section of the documentation.

The *Generate* section allows the user to produce the following output data sets:

Gridded Data: A set of 3D Gridded Data Sets for auroral electron number flux, electron energy flux, ion number flux, ion energy flux, electron average energy, ion average energy, Hall conductivity, and Pedersen conductivity is produced. The default settings for the Grid define a two-dimensional geocentric coordinate slice at the constant radius of 110 km (1.017 Re). When a three-dimensional Grid is specified with the Grid Tool, the data values from the default two-dimensional slice are mapped to the grid points along field lines determined from the user-specified magnetic field model.

Eq Edge: Field Line data sets are produced that represent the equatorward edge of the auroral electron number flux boundary and its mapping out along magnetic field lines of the user-specified magnetic field model. The following options become applicable:

Use Kp: If this option is selected the AURORA science module calculates the equatorward boundary using the Kp value

given by the Global Parameters.

Use single observation: If this option is selected the AURORA science module calculates the equatorward boundary by determining an effective Kp from a single MLT observation of the boundary location. The effective Kp is then applied to determine the boundary for the remaining MLT points. The following quantities must be entered,
MLT(hrs): The magnetic local time of the observation in decimal hours.

Obs. MLAT(deg): The magnetic latitude in Corrected Geomagnetic Coordinates of the observed equatorward boundary at the specified MLT.

Note: If the effective Kp determined from the *MLT*, *Obs. MLAT* values entered is outside of the acceptable range (Kp = 0.0 to 9.0) or if the *Obs. MLAT* value entered is not valid for the selected *MLT* value, then an error popup window will warn the user. This condition arises occasionally when observed MLT and MLAT values are input directly from the DMSP-SPECTRA data module text output window, as there are no restrictions on the effective Kp values resulting from the DMSP observations. The best resolution is to select the *Use Kp* option and set the global Kp value equal to either 0.0 or 9.0, whichever is appropriate.

Map from North: Magnetic field line mapping originates from the auroral equatorward boundary in the northern hemisphere.

Map from South: Magnetic field line mapping originates from the auroral equatorward boundary in the southern hemisphere.

Note: Magnetic field lines emanating from the northern hemisphere auroral equatorward boundary will not generally match those emanating from the southern auroral boundary. This is because no magnetic field model in AF-GEOSpace exactly matches the models used to construct CGM coordinates. The closest match arises when using the IGRF internal field for the year 1990 without an external field. The match is not exact due to interpolation and function fitting of the CGM coefficients in the CGM to geographic coordinate conversion routine used (SFC\$\$\$GEO_CONVERT_COORD).

The *Internal B-Field* section allows the user to specify which model to use for the Earth's internal magnetic field: *Dipole*, *IGRF(1945-2000)*, or *Fast IGRF*. Additional information and references on the magnetic field models can be found in the BFIELD-APP section of the documentation.

The *External B-Field* section allows the user to specify which model to use for external contributions to the magnetic field: *None*, *Hilmer-Voigt*, *Olson-Pfitzer*, *Tsyganenko '89*, or *Tsyganenko '87*. Additional information and references on the magnetic field models can be found in the BFIELD-APP section of the documentation.

The *Model* section allows the user to specify the data to drive the model. The options are:

Kp: Selects the Kp index from the Global parameters as the model driver.

IMF/SW: Selects the interplanetary magnetic field and solar wind data as model driver. When this option is chosen the following quantities must be entered:

Bz:	The value of the z-component of the interplanetary magnetic field available as six selectable values from -4.5 to 4.5 nanotesla (nT).
Vsw:	The value of the magnitude of the solar wind velocity available as five selectable values between 346 and 677 kilometers/second (km/s).

AURORA Outputs

When the Gridded Data output option is selected the AURORA science module returns the integral electron energy flux ($\text{keV}/(\text{cm}^2 \text{ s sr})$), the integral electron number flux ($\#/\text{cm}^2 \text{ s sr}$), the integral ion energy flux ($\text{keV}/(\text{cm}^2 \text{ s sr})$), the integral ion number flux ($\#/\text{cm}^2 \text{ s sr}$), the electron average energy (keV), the ion average energy (keV), the height-integrated Pedersen conductivity (mhos), and the height-integrated Hall conductivity (mhos) as separate 3D Gridded Data Sets. In the default mode, the 3D Gridded Data Set will contain only a two-dimensional constant radius slice at an altitude of 110 km (1.017 Re). When the user specifies a three-dimensional grid with the Grid Tool, a grid point is assigned a value equal to the data value existing at the point of intersection between the original constant-radius data slice at 110 km and the magnetic field line that maps through the point in question. It is thus possible to denote surfaces of field lines emanating from separate flux value isocontours at 110 km.

When the *Eq Edge* output option is selected the AURORA science module returns a Field Line Data Set containing magnetic field lines emanating from the equatorward edge of the auroral electron number flux (referred to as *Mapped Eq. Edge*). An additional Field Line data set is generated representing the equatorward edge oval (referred to as *Eq. Edge*).

The CHIME Science Module

Model Name:	CRRES/SPACERAD Heavy Ion Model of the Environment (CHIME)
Version:	3.5, December 1995
Developer:	Lockheed Martin Advanced Technology Center and AFRL, adapted to AF-GEOSpace by Radex, Inc.
References:	<p>Chenette, D. L., J.D. Tobin, and S.P. Geller, CRRES/SPACERAD Heavy Ion Model of the Environment, CHIME, <i>PL-TR-95-2152</i>, Phillips Laboratory, Hanscom AFB, MA (1995) (User's guide for Version 3.5) ADA 321996</p> <p>Chenette, D.L., J. Chen, E. Clayton, T.G. Guzik, J.P. Wefel, M. Garcia-Munoz, C. Lopate, K.R. Pyle, K.P. Ray, E.G. Mullen, D.A. Hardy, The CRRES/SPACERAD Heavy Ion Model of the Environment (CHIME) for Cosmic Ray and Solar Particle Effects on Electronic and Biological Systems in Space, <i>IEEE Trans. Nucl. Sci.</i>, 41, 2332-2339 (1994)</p> <p>Feynman, J., G. Spitale, J. Wang, and S. Gabriel, Interplanetary Proton Fluence Model: JPL 1991, <i>J. Geophys. Res.</i>, 98, 13281 (1993)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CHIME Overview

The CRRES Heavy Ion Model of the near-Earth Space Environment (CHIME) Science Module and Linear Energy Transfer (LET) Application Module are a UNIX port of the PC program CHIME developed and released under the auspices of the Air Force Research Laboratory. The following description is excerpted from the CHIME User's Manual:

"[CHIME] is a set of programs and data files which permit a user to (1) calculate accurate models of the fluxes and energy spectra of ions in the near-Earth space environment under a wide variety of conditions, (2) convert these particle flux models to linear energy transfer spectra, and (3) estimate rates for single-particle radiation effects in microelectronic devices exposed to the environmental model fluxes.... The [environment] model covers the energy range from 10 MeV/nucleon to 60 GeV/nucleon for all known stable elements, and includes the known major sources of heavy ions in the near-Earth interplanetary medium over this energy range, namely: galactic cosmic rays (GCR), the anomalous component (AC), and heavy ions from solar energetic particle events (SEP)."

The CHIME Science Module calculates ion flux models (Step 1 in the paragraph above) and produces a 3D data set as a function of geographic coordinates which can be visualized with the appropriate Graphics Modules in 1D, 2D, and 3D. Calculation of the LET spectra and single event effect (SEE) rates (Steps 2 and 3 in paragraph above) are accomplished in the LET-APP Module. The CHIME Science Module provides an option to normalize the fluxes to the regular CHIME units (particles/(m² s sr MeV/nucleon)) or the units used in the CRRESPRO trapped proton model (particles/(m² s MeV)). Using the CRRESPRO units, intensities of the cosmic rays and solar energetic particles can be directly compared to the intensity in the radiation belts.

The models for the GCR and AC are described as follows in the CHIME User's manual:

"The long-term time- and energy-variations of the GCR and AC heavy ions near earth are well understood as the result of 'modulation' by the sun of a set of 'local interstellar spectra' (LIS) defined at the outer boundary of the heliosphere. The amount of this modulation is described by a single parameter for all particle species: the solar modulation parameter, Φ , which is in units of electric potential, typically megavolts (MV).

CHIME contains a comprehensive [GCR] data base describing the heavy ion flux environment near earth under the full range of expected solar modulation conditions. This database is a set of differential (in energy) heavy ion fluxes as a function of kinetic energy (E) and Φ . The E , Φ range covered by this database is from 10 MeV/nucleon to 60 GeV/nucleon in kinetic energy and 300 MV through 1700 MV in solar modulation level. All ions from hydrogen ($Z=1$) through nickel ($Z=28$) are tabulated. Ions heavier than nickel are modeled using abundance ratios to iron. [...]

For the elements He, N, O, and Ne an additional component, the anomalous component (AC), is also tabulated in the database. The AC was calculated using the same solar modulation code and for the same range of solar modulation as the GCR flux. Due to the nature of this source, however, the AC-LIS decrease very rapidly with increasing energy compared to the GCR-LIS. Thus the AC fluxes become insignificant compared to the GCR fluxes above a few hundred MeV per nucleon. Additionally, in the solar modulation calculation the AC was treated as singly charged, and the AC charge state is assumed to be 1 (singly charged) in the calculation of the geomagnetic shielding [described below]."

Solar Energetic Particles are treated in a variety of ways as described in the CHIME User's Manual excerpts that follow.

"Several different SEP models are incorporated into CHIME. These include models based on measurements made during the CRRES mission and models based on statistical distributions of energetic solar proton event intensities. The user of CHIME may select any one of these models to add to the GCR and AC fluxes determined as described [above]."

"The two largest SEP events observed during the CRRES mission occurred in March and June 1991. Due to the significance of these events to CRRES investigations, they are made directly available for use in CHIME. The March event was an "iron-rich" event, but with a significantly softer energy spectrum than the June event (see *Chen et al. [Adv. Space. Res., 14, 675, 1994]* for a more detailed description of these events). Thus for very thin amounts of passive shielding, the March environment was more severe than that for June.... The user can select the peak instantaneous flux or the highest 24-hour average flux for either event."

"For predictive purposes CHIME also provides heavy ion fluence models as a function of mission duration and probability of occurrence. (In this context fluence refers to flux integrated over time.) These models are based on the "Interplanetary Proton Fluence Model: JPL 1991" [*Feynman et al., 1993*]. This is a statistical description of the observed distribution of energetic solar proton event sizes. For a given mission start date and duration, the model provides a proton fluence spectrum which would be exceeded at a probability of occurrence, or confidence level, selected by the user (from 50% to 0.1%). Heavy ion fluences as a function of energy are scaled from the proton fluence spectrum using a table of

energy independent, average solar energetic particle event, ion composition factors.

It is important to remember that the JPL 1991 model describes ion fluences, which are fluxes integrated over a specific time interval. If a time interval is specified by the user in defining the GCR and AC fluxes, that same interval will be used in the SEP model if the JPL 1991 model is selected.”

To compute the GCR, AC, and SEP particle fluxes in the near-Earth region magnetically shielded by the Earth’s magnetosphere (taken to be radial distances less than 15 Earth radii in CHIME) a geomagnetic cutoff model is employed as described in the CHIME User’s Manual:

“The model is based on an offset, tilted dipole approximation for the earth’s magnetic field [Wilson *et al.*, NASA Ref. Pub. 1257, 475, 1991]. Despite its simplicity, this model captures the major features of the combined total average geomagnetic shielding effect with good accuracy.... [For each point on the user-specified grid in the CHIME science module], the GEOMAG Transmission function in CHIME calculates the access solid angle as a function of the ion energy and applies this filter function to the interplanetary heavy ion flux calculated by the procedures described [above]... The transmission filter is applied separately to the GCR[+SEP] and AC spectra. While the GCR[+SEP] source is assumed to consist of fully stripped ions ($Q=Z$), the AC is treated as singly charged ($Q=1$) in this part of the calculation.”

Note: The CHIME science module has not been optimized and can take a significant amount of run time on high resolution grids.

CHIME Inputs

Input to the CHIME science module comprises the environment inputs required to run the model and the requested particle limits for the output fluxes.

Specify environment:

Flux Input:	Several methods for generating cosmic ray fluxes (Galactic Cosmic Rays/ Anomalous Component Spectra) are provided. The options are:
Off:	No cosmic ray fluxes generated.
Modulation:	CHIME provides fluxes corresponding to the “Level” (entered in the text box, approximate range: 400 to 1600 megavolts) of solar modulation selected from a full range of monthly values over the period 1970-2010.
Period:	CHIME computes the average of the fluxes for each ion species over the user-specified time interval entered in the “Year 1”, “day 1”, “Year 2”, and “day 2” text boxes activated when this option is selected. Tabulated monthly values of the solar modulation parameter for the period 1970-2010 are used.
Solar Events:	The CHIME model provides several models for specifying the flux or fluence of heavy ions originating at the Sun as a result of solar energetic particle (SEP) events. The options are:

Off:	No SEP event related flux/fluence is generated.
March 91 Peak:	Model based on peak CRRES measurements from the March 1991 event
June 91 Peak:	Model based on peak CRRES measurements from the June 1991 event
March 91 Ave:	Model based on average CRRES measurements from the March 1991 event
June 91 Ave:	Model based on average CRRES measurements from the June 1991 event
JPL 1991 Model:	Models based on statistical distributions of solar proton event intensities (JPL 1991, <i>Feynmann et al.</i> , [1993]). It provides the proton fluence which would be exceeded at a probability level of occurrence (<i>Pr</i>), or confidence level, from 50% to 0.1%. If the <i>Flux Inputs</i> option <i>Off</i> or <i>Period</i> is selected above, then fluxes are calculated from the fluences using the user-specified time interval. If <i>Modulation</i> is selected as the <i>Flux Inputs</i> option, then a random period of 1 year is used.

Note: The cosmic ray flux input and solar event options are identical to those used in the LET-APP Module.

Galactic cosmic ray (GCR) and solar energetic particles (SEP):

Atomic Z(1-28):	The range (Min, Max) of species atomic Z value.
Energy(MeV/n):	The energy range (Min, Max) of the particles.

The Anomalous component cosmic ray (AC) particles:

Mass(4-20):	The mass range (Min, Max) of the particles.
Energy(MeV/n):	The energy range (Min, Max) of the particles.

Flux Units: Two proton output flux unit options are available:

CHIME:	Flux is given in units of $\#/(m^2 \text{ s sr MeV/n})$.
CRRESPRO:	Omni-directional flux is given in units $\#/(cm^2 \text{ s MeV/n})$.

CHIME Outputs

The CHIME science module outputs a 3D gridded data set of either the cosmic ray and/or solar event fluxes or the anomalous cosmic ray fluxes. Output units are $\#/(m^2 \text{ s sr MeV/nucleon})$ if CHIME units were chosen or $\#/(cm^2 \text{ s MeV/nucleon})$ if CRRESPRO units were chosen.

The CRRESELE Science Module

Model Name: CRRESELE

Version: July 1995

Developer: Air Force Research Laboratory

References: Brautigam, D.H., and J. Bell, CRRESELE Documentation, *PL-TR-95-2128*, Phillips Laboratory, Hanscom AFB, MA (1995), ADA 301770

Brautigam, D.H., M.S. Gussenhoven, and E.G. Mullen, Quasi-static Model of Outer Zone Electrons, *IEEE Trans. Nucl. Sci.*, **39**, 1797-1803 (1992)

Olson, W.P., and K.A. Pfitzer, Magnetospheric Magnetic Field Modeling, Annual Scientific Report, Air Force Office of Scientific Research contract F44620-75-C-0033, McDonnell Douglas Astronautics Co., Huntington Beach, CA (1977), ADA 037492

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESELE Overview

The CRRESELE science and application modules are a UNIX port of the PC program CRRESELE developed and released by the Air Force Research Laboratory. The following description of CRRESELE is excerpted from the CRRESELE documentation:

“CRRESELE utilizes electron radiation belt models constructed from data measured by the High Energy Electron Fluxmeter (HEEF) flown on the Combined Release and Radiation Effects Satellite (CRRES). CRRES flew in a geosynchronous transfer orbit for 14 months during solar maximum. The electron models are omnidirectional flux maps binned in L shell and B/B₀ (azimuthal symmetry is assumed) for a given energy. The CRRESELE utility [uses these models] to calculate electron omnidirectional fluences (differential or integral) for 10 energy intervals (0.5-6.60 MeV). A user-specified orbit is traced through eight different outer zone electron flux models, at each energy, to provide an estimate of electron fluences received by a satellite under a wide range of magnetospheric conditions. Six of the eight CRRESELE models are parameterized by geomagnetic activity [using the Ap15 index], the seventh is simply a mission average, and the eighth is constructed from maximum flux values. Caution must be used when interpreting the results [of fluence calculations using the electron models] because CRRESELE is restricted to modeling the outer zone electrons [from L=2.5-6.8] and, consequently, excludes any electron fluence contributions from the inner zone and slot region.”

Central to the construction of the CRRESELE electron models is the new geomagnetic activity index, Ap15, defined as follows in the CRRESELE Documentation:

“For the purpose of constructing the [CRRESELE electron flux models] we define a new index derived from the Ap value. For a given day, the preceding 15 daily values of Ap are averaged to form the Ap15 index. The Ap15 index may be derived from either the estimated (NOAA-USAF Space Environment Services Center, Preliminary Report and Forecast of Solar Geophysical Data) or archived (NOAA World Data Center-A, Solar

Geophysical and Prompt Reports) Ap values; the results agree within plus/minus 20% and display the same qualitative variations. A linear regression was performed of 455 days of estimated and archived indices and yielded the following linear relation: $Ap15(\text{estimated}) = 0.8 * Ap15(\text{archived}) + 2.6$, with a correlation coefficient of 0.99. When Ap15 is referred to in this document, it is assumed that it is derived either directly from the weekly estimated Ap or indirectly (via the linear relationship given above) from the archived version of Ap.”

The CRRESELE science module is used to map the electron flux models used by CRRESELE into a three-dimensional grid specified by the user. A variety of magnetic field models can be used for the mapping. The eighty electron flux models used in CRRESELE were derived from the CRRES data as explained by the following excerpt from the CRRESELE Documentation,

“The 0.512 second count rates [from each of the 10 energy channels of the HEEF instrument] are first binned by L (0.05 Re bins) and pitch angle (5 degree wide bins), folding the pitch angles > 90 degrees into the 0-90 degree quadrant. Various correction algorithms are next applied to these average count rates, which are then converted to average fluxes. For a given energy and L, the bin average pitch angle distributions are mapped to the magnetic equator [using the Olson-Pfizer static external magnetic field model and the IGRF85 internal magnetic field model]. A database of daily average equatorial fluxes binned by day, energy, pitch angle, and L ($2.5 \leq L \leq 6.55$) is then created. [The data is then extrapolated to $L=6.68$ by using a linear least-squares fit to the data from $L=6.0-6.55$ for each equatorial pitch angle bin and energy channel.] This database is next sorted into eight models... Six of the eight models are parameterized by geomagnetic activity. The Ap15 index [described above] is determined for each day of the CRRES mission using NOAA’s weekly published values for the estimated daily planetary index ($\sim Ap$) (SESC, 1990-1991)... The lowest Ap15 values represent very quiet magnetospheric conditions, during which one can expect to find lower fluxes peaking at higher Ls. Likewise, the highest Ap15 values represent very active magnetospheric conditions, during which one can expect to find higher flux values peaking at lower L’s [Brautigam *et al.*, 1992]. [...] The range of Ap15 observed during the CRRES period ($Ap15 = 6$ to 55) is divided into six intervals (5-7.5, 7.5-10, 10-15, 15-20, 20-25, 25-55). The daily average flux database described above is then sorted according to the corresponding daily Ap15 value. [...] This procedure results in six electron equatorial flux models for each of the 10 energies. [...] Two additional models, independent of Ap15, are constructed from the same average flux database referred to above. For [the first additional model] the entire database is averaged together providing a mission averaged model. [The second additional model] is constructed from the maximum flux found at each L bin of the daily averages.”

After the user selects a flux model, the CRRESELE science module calculates the B/L coordinates for each grid point in the user-specified magnetic field model. The resulting flux is then obtained from the B/L coordinates and the chosen data file and then assigned to the grid point. In this manner, a fully three-dimensional map of the outer zone flux data may be made from the CRRES data.

Note: Although AF-GEOSpace allows the data to be mapped in three dimensions using a variety of magnetic field models, the original CRRES data was binned into B/L coordinates using the IGRF85 magnetic field with the *Olson-Pfizer* (1977) external field.

The user should be aware that using other magnetic field models to map the data to three-dimensional space is inconsistent with the original reduction of the data.

CRRESELE Inputs

The CRRESELE science module requires the user to specify the following information to determine which data set to use and which magnetic field model to use in mapping the data,

B-Model:	The magnetic field model used to convert from the B-L coordinates of the model to three-dimensional space. The default is the model used to reduce the CRRES data, i.e., <i>IGRF85/O-P</i> . The <i>B-Model</i> options include:
Dipole:	A dipole field
Dipole-Tilt:	A tilted dipole field
Dip-Tilt-Off:	A tilted-offset dipole field
IGRF85:	The International Geomagnetic Reference Field (1985) with no external contributions.
IGRF85/O-P:	The <i>IGRF85</i> internal field with the <i>Olson and Pfitzer</i> (1977) static model to represent the external field.

Note: The *IGRF85* internal field uses the Year, Day, and UT Global Parameters. Though less consistent with the original data reduction, models are computed significantly faster when one of the dipole field options is chosen.

Energy Channel:	The energy channel parameter selects which of the ten flux models corresponding to the ten HEEF energy channels with central energies between 0.65 and 5.75 MeV is to be considered.
Ap15 Model Range:	The Ap15 parameter specifies which of the six flux model sets corresponding to the six geomagnetic activity levels (Ap15 = 5-7.5, 7.5-10, 10-15, 15-20, 20-25, or 25-55) is to be considered. Also possible is the choice of the mission average (<i>AVE</i>) or the mission maximum (<i>MAX</i>) model sets.
Global Ap15:	Pushing the <i>Compute</i> button causes an automatic calculation of the 15 day average of the Ap index (Ap15) based on the chosen global parameter set, i.e. <i>Archive</i> , <i>Recent</i> , or <i>Latest</i> , and displays the value in the window. If the parameter records are insufficient to compute Ap15 then the value will be labeled as missing.

CRRESELE Outputs

The CRRESELE science module returns a 3D Gridded Data Set of the electron flux for the selected energy channel and activity level (including *AVE* and *MAX*) in units of $\#/(cm^2 s keV)$.

The CRRESPRO Science Module

Model Name: CRRESPRO

Version: 28 July 1994

Developer: Air Force Research Laboratory

References: Meffert, J.D., and M.S. Gussenhoven, CRRESPRO Documentation, *PL-TR-94-22/8*, Phillips Laboratory, Hanscom AFB, MA (1994), ADA 284578

Gussenhoven, M.S., E.G. Mullen, M.D. Violet, C. Hein, J. Bass, and D. Madden, CRRES High Energy Proton Flux Maps, *IEEE Trans. Nucl. Sci.*, **40**, 1450-1457 (1993)

Olson, W.P., and K.A. Pfitzer, Magnetospheric Magnetic Field Modeling, Annual Scientific Report, Air Force Office of Scientific Research contract F44620-75-C-0033, McDonnell Douglas Astronautics Co., Huntington Beach, CA (1977), ADA 037492

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESPRO Overview

The CRRESPRO science and application modules are UNIX ports of the PC program CRRESPRO developed by the Air Force Research Laboratory. A CRRESPRO Documentation excerpt:

“CRRESPRO predicts proton omnidirectional fluence per year and integral omnidirectional fluence per year at selected energies in the range 1-100 MeV for an orbit specified by the user. It closely parallels its counterpart, CRRESRAD, which predicts dose behind four thicknesses of hemispherical aluminum shielding. [...] The CRRESPRO software uses flux models created from data collected by the proton telescope (PROTEL) on board the Combined Release and Radiation Effects Satellite (CRRES) flown from 25 July 1990 to 12 October 1991 during solar maximum. CRRES was in a geosynchronous transfer orbit with an inclination of 18 degrees, a perigee of 350 km, and an apogee of 33000 km. It traversed the radiation belts twice per orbit with a period of 9 hours 52 minutes. In March 1991, a magnetic storm caused a reconfiguration of the inner magnetosphere, resulting in, among other features, double proton belts forming over a certain energy range. Because of this change, two CRRES models were created. The quiet model uses data from July 1990 to March 1991, and the active model uses data from March 1991 to October 1991. Note that in this documentation and the CRRESPRO software, “quiet” refers to the period from July 1990 to March 1991 (single proton belt) and “active” refers to March 1991 to October 1991 (double proton belt). Quiet and active as used here for the inner radiation belt have no correspondence to quiet and active as determined by Kp. In fact, the average Kp for the two CRRES periods was the same, namely 2.2.”

The CRRESPRO science module is used to map the proton flux data sets used by CRRESPRO onto a three-dimensional grid specified by the user. A variety of magnetic field models can be used for the mapping. Forty-four data sets were derived from the CRRES data as described by the following excerpt from the CRRESPRO documentation:

“The flux models used by CRRESPRO are based on in situ flux measurements made by CRRES. [...] The instrument used to measure flux on CRRES was the proton telescope (PROTEL). PROTEL had two detector heads, which together measured protons from 1 to 100 MeV in 24 energy steps, giving a complete spectrum every 1.024 seconds. The angular resolution of the detector low (high) energy head was +/- 10 degrees by +/- 10 degrees (+/- 12 degrees by +/- 17 degrees). [...] For the CRRES proton models, a data base of differential number flux values on the magnetic equatorial plane was created using each PROTEL data point. The in situ values were mapped point by point to the magnetic equator conserving the first adiabatic invariant in the combined IGRF85 and Olson-Pfizer quiet magnetic field model. The equatorial data were averaged by channel for each leg of each orbit in L shell bins of extent 1/20th Re and pitch angle bins of width 5 degrees. The equatorial data from all orbits occurring before (after) the March 1991 storm were then combined in the same L and pitch angle bins to create the CRRES quiet (active) proton model. [...] In summary, we have created two proton models from the CRRES PROTEL data base: a quiet model using data acquired before the March 1991 storm and an active model using data acquired after the storm. Each model potentially consists of twenty-four sub models, one for each energy channel. [...] We eliminate one of the 8.5 MeV channels and the 15.2 MeV channel [see full documentation for discussion]. This results in 44 different flux model files.”

After selecting a proton data set, the module calculates the B/L coordinates for each grid point in the user-specified magnetic field model. Resulting flux values are then obtained from the B/L coordinates and the chosen data file and assigned to the grid point. In this manner, a fully three-dimensional map of the proton flux data may be made from the CRRES data.

Note: Although AF-GEOSpace allows the data to be mapped in three dimensions using a variety of magnetic field models, the original CRRES data was binned into B/L coordinates using the IGRF85 magnetic field with the *Olson and Pfizer* (1977) external field. The user should be aware that using other magnetic field models to map the data to three-dimensional space is inconsistent with the original reduction of the data.

CRRESPRO Inputs

The CRRESPRO science module requires the user to specify the following information to determine which data set to use and which magnetic field model to use in mapping the data,

B-Model:	The magnetic field model used to convert from the B-L coordinates of the model to three-dimensional space. The default is the model used to reduce the CRRES data, i.e., <i>IGRF85/O-P</i> . The <i>B-Model</i> options include:
Dipole:	A dipole field
Dipole-Tilt:	A tilted dipole field
Dip-Tilt-Off:	A tilted-offset dipole field
IGRF85:	The International Geomagnetic Reference Field (1985) with no external contributions.
IGRF85/O-P:	The <i>IGRF85</i> internal field with the <i>Olson and Pfizer</i> (1977) static model to represent the external field.

Note: The *IGRF85* internal field uses the Year, Day, and UT Global Parameters. Though less consistent with the original data reduction, models are computed significantly faster when one of the dipole field options is chosen.

Energy Channel: The energy channel parameter selects which of the proton flux data sets corresponding to the twenty-two PROTEL energy channels between 1 and 100 MeV is to be considered.

Activity: The activity parameter specifies whether the *Quiet* (obtained before the 24 March 1991 storm) or *Active* (obtained after the 24 March 1991 storm) proton flux data sets are to be used.

CRRESPRO Outputs

The CRRESPRO science module returns a 3D Gridded Data Set of the proton flux for the selected energy channel and activity level in units of $\#/(cm^2 \text{ s MeV})$.

The CRRESRAD Science Module

Model Name: CRRESRAD

Version: August 1992

Developer: Air Force Research Laboratory

References: Kearns, K.J., and M.S. Gussenhoven, CRRESRAD Documentation, *PL-TR-92-2201*, Phillips Laboratory, Hanscom AFB, MA (1992), ADA 256673

Gussenhoven, M.S., E.G. Mullen, M. Sperry, K.J. Kerns, and J.B. Blake, The Effect of the March 1991 Storm on Accumulated Dose for Selected Satellite Orbits: CRRES Dose Models, *IEEE Trans. Nuc. Sci.*, **39**, 1765-1772 (1992)

Gussenhoven, M.S., E.G. Mullen, D.H. Brautigam, E. Holeman, C. Jordan, F. Hanser, and B. Dichter, Preliminary Comparison of Dose Measurements on CRRES to NASA Model Predictions, *IEEE Trans. Nucl. Sci.*, **38**, 1655-1662 (1991)

Olson, W.P., and K.A. Pfitzer, Magnetospheric Magnetic Field Modeling, Annual Scientific Report, Air Force Office of Scientific Research contract F44620-75-C-0033, McDonnell Douglas Astronautics Co., Huntington Beach, CA (1977), ADA 037492

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESRAD Overview

The CRRESRAD application is a UNIX port of the PC program CRRESRAD developed and released by the Air Force Research Laboratory. A CRRESRAD Documentation excerpt:

“CRRESRAD predicts the amount of radiation received in a specified orbit behind four hemispheres of aluminum with thicknesses of 82.5, 232.5, 457.5, and 886.5 mils. The prediction uses empirical models of accumulated dose measured on the Combined Release and Radiation Effects Satellite (CRRES) flown from 25 July 1990 to 12 October 1991 during solar maximum. CRRES was in a geosynchronous transfer orbit with an inclination of 18 degrees, a perigee of 350 km and an apogee of 33000 km. CRRES traversed the radiation belts twice per orbit with a period of 9 hours 52 minutes. The instrument used to measure accumulated dose is the CRRES Space Radiation Dosimeter which measures both dose rate and accumulated dose in four silicon detectors each of which is behind an aluminum dome of different thickness. The minimum energies required for particles to penetrate the domes and accumulate dose in the silicon detectors underneath are 20, 35, 50 and 75 MeV for protons and 1, 2.5, 5 and 10 MeV for electrons. Dose from particles depositing 0.05-1 MeV and 1-10 MeV is accumulated in two different channels called LOLET and HILET, respectively. HILET dose accumulates primarily from protons with energies of 20-100 MeV, but electrons with energies > 5 MeV may contribute during large electron enhancement periods. LOLET dose accumulates from electrons, bremsstrahlung, and protons with energies > 100 MeV.”

The CRRESRAD science module is used to map the radiation dose rate data sets from the CRRES mission onto a three-dimensional grid specified by the user. A variety of magnetic field models can be used for the mapping. Thirty-six data sets were derived from the CRRES data as described by the following excerpt from the CRRESRAD documentation:

“The dose models used by CRRESRAD are based on in situ dose rate measurements made by CRRES. The instrument used to measure dose is the CRRES Space Radiation Dosimeter. [...] The dosimeter measured accumulated dose once every 4.096 seconds throughout the CRRES mission. The measured dose rates for each dome were binned by L shell and B/B_0 to make average dose rate models in rads (Si) per second. The width of each bin in L shell is $1/20 R_e$, and the width of each bin in B/B_0 is ~ 2 degrees latitude in a dipole field. The bins form a two dimensional array of 140 (L Shell) by 20 (B/B_0) and cover L shells from 1 to 8 R_e and magnetic latitudes of 0 degrees to ~ 40 degrees. The CRRES mission is divided into two parts. The magnetosphere is assumed to be in a quiet configuration before the March 1991 storm and in an active configuration after the March storm. A model was made separately for LOLET, HILET and LOLET+HILET for each of the four domes. Three sets of these models were made: one for quiet conditions before the storm (27 July 1990 to 19 March 1991), one for active conditions after the storm (31 March 1991 to 12 October 1991) and one for average conditions over the entire mission (27 July 1991 to 12 October 1991). These combinations result in 36 different dose rate models.”

After the user selects which dataset is desired, the CRRESRAD science module calculates the B/L coordinates of each grid point from the user-specified magnetic field model. The resulting dose rate is then obtained from the B/L coordinates and the chosen data file. In this manner, a fully three-dimensional map of the dose rate data may be made from the CRRES data.

Note: Although AF-GEOSpace allows the data to be mapped in three-dimensions using a variety of magnetic field models, the original CRRES data was binned into B/L coordinates using the IGRF85 magnetic field with an *Olson and Pfitzer* (1977) external field. The user should be aware that using other magnetic field models to map the data to three-dimensional space is inconsistent with the original reduction of the data.

CRRESRAD Inputs

The CRRESRAD science module requires the user to specify the information to determine which data set to use and which magnetic field model to use in mapping the data,

B-Model:	The magnetic field model used to convert from the B-L coordinates of the model to three-dimensional space. The default is the model used to reduce the CRRES data, i.e., <i>IGRF85/O-P</i> . The <i>B-Model</i> options include:
Dipole:	A dipole field
Dipole-Tilt:	A tilted dipole field
Dip-Tilt-Off:	A tilted-offset dipole field
IGRF85:	The International Geomagnetic Reference Field (1985) with no external contributions.
IGRF85/O-P:	The <i>IGRF85</i> internal field with the <i>Olson and Pfitzer</i>

(1977) static model to represent the external field.

- Shielding: The shielding parameter specifies whether the 82.5, 232.5, 457.5 or 886.5 *mil* aluminum hemisphere shielding thickness data set is to be used.
- Channel: The channel parameter specifies which dose rate data set is to be used:
- LoLet: (0.05-1 MeV deposited from electrons, bremsstrahlung, and > 100 MeV protons)
 - Hi/Lo Let: (0.05-10 MeV deposited) = *LoLet* + *HiLet*
 - HiLet: (1-10 MeV deposited from 20 - 100 MeV protons and > 5 MeV electrons during large enhancement periods)
- Activity: The activity parameter specifies whether the *Quiet* (obtained before the 24 March 1991 storm), *Active* (obtained after the 24 March 1991 storm), or *Average* (average of the *Active* and *Quiet* intervals) dose rate data sets are to be used.

CRRESRAD Outputs

The CRRESRAD science module returns a 3D Gridded Data Set of the dose rate in units of Rads Si/second for the selected shielding level and detector combination.

The ISPM Science Module

Model Name: Interplanetary Shock Propagation Model (ISPM)

Version: 94

Developer: M. Dryer and Z. Smith, NOAA Space Environment Center

References: Smith, Z.K., M. Dryer, and L.D. Lewis, User's Manual, Volume II of the Interplanetary Shock Propagation Model: 1994, Final Contract Report GLH3-611, Phillips Laboratory, 31 March (1994)

Smith, Z.K., and M. Dryer, Detailed Documentation of the ISPM, Volume IV of the Interplanetary Shock Propagation Model: 1994, Final Contract Report GLH3-611, Phillips Laboratory, 31 March (1994).

The preceding document is also available as:

Smith, Z. and M. Dryer, The Interplanetary Shock Propagation Model: A Model for Predicting Solar-Flare-Caused Geomagnetic Storms, Based on the 2 1/2 D, MHD Numerical Simulation Results from the Interplanetary-Global Model (2D IGM), *NOAA Tech. Mem. ERL SEL-89*, (1995)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

ISPM Overview

The ISPM science module comprises the Interplanetary Shock Propagation Model which was developed to estimate the characteristics of interplanetary shocks caused by energetic solar events. We hereafter refer to these shock-producing solar events, whether they be coronal mass ejections or solar flares, as 'solar flares' since flare data are a crucial input to the model. This description of ISPM is excerpted from the User's Manual:

"The ISPM program calculates the arrival time and strength at 1 AU of a shock from a solar flare. The shock strength is characterized by the jump in dynamic pressure across the shock front: this parameter is used to estimate the likelihood of the shock being geo-effective. The arrival time and strength are calculated from algebraic equations derived from a parametric study of solar-caused interplanetary shocks that was made using [two-dimensional magnetohydrodynamic] simulations."

ISPM is based on magnetohydrodynamic computations of a shock wave initiated at the Sun which propagates through a normal solar wind. The initial energy of the shock is estimated by a formulation based on the X-ray energy output of a solar flare and the associated speed derived from the Type II frequency drift rate. The angular extent of the shock wave from the presumed solar flare location is a function of the energy estimated by this formulation.

As input, the ISPM requires specification of the flare location, start time of the shock, shock driver duration, and initial shock speed. The flare location (solar latitude and longitude) is obtained from H-alpha observations made by USAF SOON sites. The shock start time is defined as the onset time of the Type II radio burst associated with the flare as observed by the USAF RSTN sites. Initial shock speed is set to the Type II drift speeds estimated by the RSTN sites. Shock duration times can either be directly input or estimated from the decay time of the soft X-ray event associ-

ated with the solar flare. If the X-ray level option is chosen, the ISPM assumes the shock driver end time to be the time at which the logarithm of the magnitude of the GOES satellite 1-8 Angstrom X-ray signal falls to one-half the logarithm of the peak value observed for the event.

For output, the ISPM gives the predicted transit time (TT) of the shock from Sun to Earth and its strength in terms of the dynamic pressure jump (DPJ) across the shock front and the shock strength index (SSI). According the ISPM User's Manual, the SSI "is based on the difference of (the log10 of) the DPJ from the [background] state used in the numerical modeling study." If the SSI is greater than or equal to zero then the shock will likely be geo-effective. If SSI is less than -1 there will likely be no measurable effects. TT and DPJ are provided by numerical algorithms which relate TT and DPJ to total net energy (E) input by the solar source into the interplanetary medium as a function of angular separation ϕ between observer and solar source. The algorithms were constructed in algebraic form from a parametric study which used representative combinations of the shock starting velocity and starting pulse width and duration.

The range of applicability is given by *Smith and Dryer* [1994] as follows,

Solar flare input energy, E	$E > 10^{29}$ erg
Angular distance of pulse central meridian from Earth-sun line, ϕ	$-90 \text{ deg} < \phi < 80 \text{ deg}$
Transit time, TT	$TT < 120$ hours

The flare input energy can be estimated from the pulse duration time T_d and the initial shock speed V_s according to the formula, $E = C * \omega * (T_d + D) * (V_s^3)$ with $C = 2.83e+19 \text{ erg}/(\text{m}^3 \text{ s}^2 \text{ deg})$, the pulse longitudinal width $\omega = 60$ degrees, and $D = 0.52$ hours. Total energy is assumed to be proportional to kinetic energy flux, i.e., V_s^3 . The spatial input pulse shape is a sine curve of width ω , where the area under the sine curve is proportional to ω . The temporal input pulse has a flat section of width T_d with 1-hour ramps at the beginning and end of the pulse.

ISPM Inputs

The ISPM science module requires the following inputs:

Global Parameters: None

Specify Event Duration: The user can choose to specify either the *Stop Time* of the event, the *Duration* of the event, or have the event duration estimated from inputs of the associated GOES soft X-ray Levels.

Event onset time: Time of onset of Type II radio burst from USAF RSTN site in the format MM/DD/YY HH:MM.

Event end time: When *Stop Time* is selected to specify the event duration, the user inputs here the event end time in the format MM/DD/YY HH:MM. GOES satellite X-ray levels are not used to estimate the event duration. The ISPM resets any duration greater than 2 hours to 2 hours.

Event duration: When *Duration* is selected to specify the event duration the user inputs the event duration in hours here. GOES satellite X-ray levels are not used to estimate the event duration. The ISPM resets any duration greater than 2 hours to 2 hours.

Backg. Class: When *X-ray Levels* is selected to specify the event duration, the user inputs here the background X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite before the event occurred. These values are entered with a classification letter and a numeric field. The usual X-ray event classification letters A, B, C, M, or X can be used with the numeric field consisting of 1-3 characters which may be digits or an optional decimal point. The numeric field multiplies the flux level. The range of allowed values is A1 through X99.

Peak. Class: When *X-ray Levels* is selected to specify the event duration, the user inputs here the peak X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite during the X-ray event. The format is the standard X-ray event classification scheme as explained above. After entering this value the user should click in the *Decay time* box and the level corresponding to 1/2 log of the peak signal will be displayed next to this box.

Decay time, level XN.N: When *X-ray Levels* is selected to specify the event duration the user inputs here the time in the format MM/DD/YY HH:MM at which the X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite during the X-ray event decays to the level XN.N. The *level XN.N* is calculated from the *Backg. Class.* and *Peak. Class.* Of course, this time will occur after the peak of the X-ray event.

Type II speed(km/s): The Type II drift speed in km/s calculated by the USAF RSTN network from observations of Type II radio bursts. This value must be greater than 0 and less than 10000 km/s.

Flare lat. (deg N): The solar latitude, between -90° and +90° North, of the solar flare associated with the Type II radio burst. This information can be obtained from H-alpha observations by the USAF SOON sites. Degrees South are entered as negative numbers. ISPM does not use this input.

Flare lon. (deg W): The solar longitude, between -180° and +180° West, of the solar flare associated with the Type II radio burst. This information can be obtained from H-alpha observations by the USAF SOON sites. Degrees East are entered as negative numbers. Note: Flare locations beyond the limb are unrealistic.

Event in previous 24 hours?: If the user selects *Yes*, then the following guidelines concerning the interpretation of the ISPM are displayed in a text window:

If an event has occurred in the previous 24 hours, you need to check for possibility of interaction of the shock from this event with that from the previous event.

If the first shock arrives well before the expected arrival of the second shock, the first shock is independent. If not, you need to look at the relative spacing of sources in space and time.

If the source of the first shock (F1) is within 25 deg of Central Meridian (CM) [the Earth-Sun line] its reverse shock (R1) will interact with the forward shock of the following event (F2). If R1 is strong enough, F2 may be significantly weakened or even annihilated in the interaction. In this case, F1 may travel independently to 1AU. (Note: reverse

shocks form some 5-10 hours after initiation of a flare. If the time interval between the two flares is too short, the reverse shock may not have had time to form).

If not, F1 is likely to be overtaken. In this case, the ISPM prediction does not apply to either F1 or F2.

The shock from the second event (F2) will be independent if:

1. F2 is significantly faster than F1, its source is located closer to CM than F1 and it starts soon after F1 (within a few hours).
2. F2 travels independently for the majority of its transit time to Earth. That is:
 - a. It does not encounter R1 (source of F1 is >30 deg from CM).
 - b. It does not travel through the high speed wake of F1.

In case 2.a, an encounter with a reverse shock will weaken or annihilate a fast forward shock. The exact nature of the resultant of the interaction depends on the relative strength of the interacting shocks. In case 2.b, traveling through the disturbed (high speed, low density) wake of a preceding fast forward shock will accelerate the following shock.

If a prediction for the previous event is not available you can get it by running ISPM for it separately.

Display Text: Clicking this button will display the text output window if currently closed.

ISPM Outputs

ISPM returns a text message window containing the results of the model calculations and a summary of the input parameters. The model outputs are:

Time of shock arrival at Earth in the format YYYY MM DD HHMM (Zulu)

Total propagation time in the format HH MM

Shock Strength (the dynamic pressure jump, DPJ) in units of dynes/cm²

In addition, ISPM computes the shock strength index (SSI) which is based on the difference of (the log10 of) the DPJ from the [background] state used in the numerical modeling study. If the SSI is greater than or equal to zero then the shock will likely be geo-effective. If SSI is less than -1 there will likely be no measurable effects.

The NASAELE Science Module

Model Name: NASA Trapped Electron Model AE-8

Version: National Space Science Data Center (NSSDC) Data Set PT-11B, Oct 1987

Developer: NASA/NSSDC (distributed in AF-GEOSpace with permission)

References: Complete NASA radiation belt model references are available via anonymous ftp from NSSDCA.GSFC.NASA.GOV or the World Wide Web site
<http://nssdc.gsfc.nasa.gov/space/model/magnetos/aeap.html>.
Vette, J.I., The AE-8 Trapped Electron Model Environment, *NSSDC/WDC-A-RS 91-24* (1991)
Vette, J.I., The NASA/National Space Science Data Center Trapped Radiation Environment Model Program (1964-1991), *NSSDC/WDC-A-RS 91-29* (1991)
Jordan, C.E., NASA Radiation Belt Models AP-8 and AE-8, *GL-TR-89-0267*, Geophysics Laboratory, Hanscom AFB, MA (1989), ADA 223660

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

NASAELE Overview

The NASAELE science module computes the differential omnidirectional electron flux using the NASA AE-8 radiation belt models for ten energy intervals between 0.5 and 6.6 MeV which correspond to the ranges of the CRRES HEEF instrument data channels used in the construction of the CRRESELE science module. Two additional channels are computed that represent the energy ranges 0.04-0.5 MeV and 6.6-7 MeV covered in the NASA models but not covered by the HEEF instrument. The following NASA radiation belt models description is excerpted from the on-line summary and instructions available at the anonymous ftp site NSSDCA.GSFC.NASA.GOV:

“[The NASA radiation belt] models describe the differential or integral, omnidirectional fluxes of electrons (AE-8) and protons (AP-8) in the inner and outer radiation belts (electrons: L=1.1 to 11, protons: L=1.1 to 7) for two epochs representing solar maximum (1970) and minimum (1964) conditions. The energy spectrum ranges from 0.1 to 400 MeV for the protons and from 0.04 to 7 MeV for the electrons. AE-8 and AP-8 are the most recent ones in a series of models established by J. Vette and his colleges at NSSDC starting in the early sixties. The models are based on almost all available satellite data”.

The NASAELE science module is used to map the NASA AE-8 electron flux models for either solar maximum (AE8MAX) or minimum (AE8MIN) conditions onto a three-dimensional spatial grid specified by the user. A variety of magnetic field models can be used for the mapping.

NASAELE Inputs

The NASAELE science module requires the user to specify the following information to determine which data set to use and which magnetic field model to use in mapping the data,

Energy Channel(MeV):The energy channel parameter specifies which of 10 electron flux models,

corresponding to the 10 HEEF instrument energy channels used in the CRRESELE models, is to be used. The channels used for the CRRESELE models is to be considered. The channels span the range from 0.5-6.6 MeV. Two additional channels are included spanning the ranges above (6.6-7.0 MeV) and below (0.04-0.5 MeV) the HEEF channels covered by the NASA models.

B-Model: The magnetic field model to used to convert from the B-L coordinates of the model to three-dimensional space. The default is the model used to reduce the CRRES data, i.e., *IGRF85/O-P*. The *B-Model* options include:

Dipole:	A dipole field
Dipole-Tilt:	A tilted dipole field
Dip-Tilt-Off:	A tilted-offset dipole field
IGRF85:	The International Geomagnetic Reference Field (1985) with no external contributions.
IGRF85/O-P:	The <i>IGRF85</i> internal field with the <i>Olson and Pfitzer</i> (1977) static model to represent the external field.

Activity: The activity parameter specifies whether the *AE8MAX* (representative of solar maximum conditions) or the *AE8MIN* (representative of solar minimum conditions) electron flux models are to be used.

NASAELE Outputs

The NASAELE science module returns a 3D Gridded Data Set of the electron flux for the selected energy channel and activity level in units of $\#/(cm^2 \text{ s keV})$.

The NASAPRO Science Module

Model Name: NASA Trapped Proton Model AP-8

Version: National Space Science Data Center (NSSDC) Data Set PT-11B, Oct 1987

Developer: NASA/NSSDC (distributed in AF-GEOSpace with permission)

References: Complete NASA radiation belt model references are available via anonymous ftp from NSSDCA.GSFC.NASA.GOV or the World Wide Web site
<http://nssdc.gsfc.nasa.gov/space/model/magnetos/aeap.html>.
Vette, J.I., The AE-8 Trapped Electron Model Environment, *NSSDC/WDC-A-RS 91-24* (1991)
Vette, J.I., The NASA/National Space Science Data Center Trapped Radiation Environment Model Program (1964-1991), *NSSDC/WDC-A-RS 91-29* (1991)
Jordan, C.E., NASA Radiation Belt Models AP-8 and AE-8, *GL-TR-89-0267*, Geophysics Laboratory, Hanscom AFB, MA (1989), ADA 223660

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

NASAPRO Overview

The NASAPRO science module computes the differential omnidirectional proton flux using the NASA AP-8 radiation belt models for twenty-two energy intervals between 1 and 100 MeV which correspond to the ranges of the CRRES PROTEL instrument channels used in the construction of the CRRESPRO science module. Two additional channels are computed that represent the energy ranges 0.1-1.0 MeV and 100-400 MeV covered in the NASA models but not covered by the PROTEL instrument. The following NASA radiation belt models description is excerpted from the online summary and instructions available at the anonymous ftp site NSSDCA.GSFC.NASA.GOV:

“[The NASA radiation belt] models describe the differential or integral, omnidirectional fluxes of electrons (AE-8) and protons (AP-8) in the inner and outer radiation belts (electrons: $L=1.1$ to 11 , protons: $L=1.1$ to 7) for two epochs representing solar maximum (1970) and minimum (1964) conditions. The energy spectrum ranges from 0.1 to 400 MeV for the protons and from 0.04 to 7 MeV for the electrons. AE-8 and AP-8 are the most recent ones in a series of models established by J. Vette and his colleges at NSSDC starting in the early sixties. The models are based on almost all available satellite data”.

The NASAPRO science module is used to map the NASA AP-8 proton flux models for either solar maximum (AE8MAX) or minimum (AE8MIN) conditions onto a three-dimensional spatial grid specified by the user. A variety of magnetic field models can be used for the mapping.

NASAPRO Inputs

The NASAPRO science module requires the user to specify the following information to determine which data set to use and which magnetic field model to use in mapping the data,

Energy Channel(MeV):The energy channel parameter selects which of 22 proton flux models,

corresponding to the 22 PROTEL instrument energy channels used in the construction of the CRRESPRO models, is to be used. The channels range from 1.5 to 81.3 MeV. Two additional channels are included spanning the ranges above (100 to 400 MeV) and below (0.1 to 1.0 MeV) the PROTEL channels covered by the NASA models.

- B-Model:** The magnetic field model to used to convert from the B-L coordinates of the model to three-dimensional space. The default is the model used to reduce the CRRES data, i.e., IGRF85/O-P. The *B-Model* options include:
- Dipole: A dipole field
 - Dipole-Tilt: A tilted dipole field
 - Dip-Tilt-Off: A tilted-offset dipole field
 - IGRF85: The International Geomagnetic Reference Field (1985) with no external contributions.
 - IGRF85/O-P: The *IGRF85* internal field with the *Olson and Pfitzer* (1977) static model to represent the external field.
- Activity:** The activity parameter specifies whether the *AP8MAX* (representative of solar maximum conditions) or the *AP8MIN* (representative of solar minimum conditions) proton flux models are to be used.

NASAPRO Outputs

The NASAPRO science module returns a 3D Gridded Data Set of the proton flux for the selected energy channel and activity level in units of $\#/(cm^2 \text{ s MeV})$.

The PIM Science Module

Model Name:	Parameterized Ionospheric Model (PIM)
Version:	1.7 (13 January 1998)
Developer:	Computational Physics, Inc. and Air Force Research Laboratory
References:	Daniell, R.E., Jr., L.D. Brown, D.N. Anderson, M.W. Fox, P.H. Doherty, D.T. Decker, J.J. Sojka, and R.W. Schunk, Parameterized Ionospheric Model: A Global Ionospheric Parameterization Based on First Principles Models, <i>Radio Sci.</i> , 30 , 1499-1510 (1995)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

PIM Overview

The PIM science module is a relatively fast global ionospheric model based on the combined output of several physical ionospheric models. The following description of PIM is excerpted from *Daniell et al.* (1995),

“[The Parameterized Ionosphere Model (PIM)] is a global model of theoretical ionospheric climatology based on diurnally reproducible runs of four physics-based numerical models of the ionosphere. The four models, taken together, cover the E and F layers for all latitudes, longitudes, and local times. PIM consists of a semianalytic representation of diurnally reproducible runs of these models for low, moderate, and high levels of solar and geophysical activity and for June and December solstices and March equinox conditions.”

From a user-specified set of geophysical parameters, including year, day, UT, solar activity index F10.7, sunspot number, geomagnetic activity index Kp, and the directions of the interplanetary field components By and Bz, the PIM science module computes values of the electron density on a user-specified 3D grid. The range in altitude is 90 to 1600 km. Also computed by PIM and output on 2D grids are the height-independent critical frequencies and heights for the ionospheric E- and F2-regions (FoE, HE, FoF2, and HF2) as well as the Total Electron Content (TEC).

PIM Inputs

The PIM science module requires the following inputs:

Global Parameters:	Year, Day, UT, Kp, SSN, and F10.7. Either SSN or F10.7 can be omitted if the appropriate <i>F10.7/SSN</i> option is chosen as discussed below.				
F2 Model Norm:	This options tells PIM whether to normalize the critical frequency of the ionospheric F2-layer (FoF2). <table><tr><td>None:</td><td>No FoF2 normalization is performed.</td></tr><tr><td>URSI:</td><td>FoF2 normalization is performed using the URSI global empirical model.</td></tr></table>	None:	No FoF2 normalization is performed.	URSI:	FoF2 normalization is performed using the URSI global empirical model.
None:	No FoF2 normalization is performed.				
URSI:	FoF2 normalization is performed using the URSI global empirical model.				
E Model Norm:	This options tells PIM whether to normalize the critical frequency of the ionospheric E-layer (FoE). <table><tr><td>None:</td><td>No FoE normalization is performed.</td></tr></table>	None:	No FoE normalization is performed.		
None:	No FoE normalization is performed.				

	Empirical:	FoE normalization is performed using a semi-empirical model.
IMF By:		The orientation of the Y-component of the interplanetary magnetic field may be set to <i>Positive</i> or <i>Negative</i> .
IMF Bz:		The orientation of the Z-component of the interplanetary magnetic field may be set to <i>Positive</i> , <i>Zero</i> , or <i>Negative</i> .
F10.7/SSN:		The relationship between the instantaneous F 10.7 cm solar radio flux and the sun spot number can be set several ways, namely
	Decoupled:	The sun spot number and solar radio flux will be treated as independent quantities.
	F10.7->SSN:	The sun spot number will be estimated from the solar radio flux.
	SSN->F10.7:	The solar radio flux will be estimated from the sun spot number.
Write to File:		Specifies the file name that the PIM results should be stored in.

PIM Outputs

PIM returns the spatial distribution of the following ionospheric quantities,

Elec. Density:	The electron density ($\#/cm^3$) is returned as a 3D Gridded Data Set.
FoE:	The critical frequency (MHz) of the E layer of the ionosphere is returned as a 2D Gridded Data Set in latitude and longitude.
HE:	The altitude (km) of the peak of the ionospheric E layer is returned as a 2D Gridded Data Set in latitude and longitude.
FoF2:	The critical frequency (MHz) in the F2 layer of the ionosphere is returned as a 2D Gridded Data Set in latitude and longitude.
HF2:	The altitude (km) of the peak of the ionospheric F2 layer is returned as a 2D Gridded Data Set in latitude and longitude.
TEC:	The total electron content (height integrated electron density in units of $10^{12} cm^{-2}$) is returned as a 2D Gridded Data Set in latitude and longitude.

The PPS Science Module

Model Name:	Proton Prediction System (PPS)
Version:	96
Developer:	D. Smart and M. Shea, Air Force Research Laboratory
References:	<p>Smart, D.F., and M.A. Shea, PPS76 - A Computerized "Event Mode" Solar Proton Forecasting Technique, in <i>Solar Terrestrial Predictions Proceedings</i>, edited by R.F. Donnelly, U.S. Department of Commerce, NOAA/ERL, 1, p. 406 (1979)</p> <p>Smart, D.F., and M.A. Shea, PPS-87: A New Event Oriented Solar Proton Prediction Model, <i>Adv. Space Res.</i>, 9, No. 10, (10)281-(10)284, (1989)</p> <p>Smart, D.F., and M.A. Shea, Modeling the Time-Intensity Profile of Solar Flare Generated Particle Fluxes in the Inner Heliosphere, <i>Adv. Space Res.</i>, 12, No. 2-3, (2)303-(2)313, (1992)</p> <p>Preliminary Software User's Manual for the Proton Prediction System, Critical Design Review Data Package for the Proton Prediction Model, Prepared by C. B. Tang, Inc for contract no. F19628-87-C-0044, March (1987)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

PPS Overview

The PPS Science module is a UNIX port of the Proton Prediction System (PPS) program developed by the Air Force Research Laboratory. Previous versions for DOS PCs have been released. As *Smart and Shea* (1979) explain:

"[PPS] has been developed to generate a computerized time-intensity profile of the solar proton intensity expected at the Earth after the occurrence of a significant solar flare on the sun. This procedure is a combination of many pieces of independent research and theoretical results. It is not a comprehensive self-consistent analytical method, but is a construction of selected experimental and theoretical results from the entire domain of solar-terrestrial physics."

PPS has been constructed to model protons that are accelerated during energetic solar events (i.e., those associated with flares) near the solar surface. It does NOT model proton acceleration that might occur in an interplanetary shock propagating towards the Earth. Most proton events at Earth are the result of protons accelerated near the solar surface. 'Hybrid' solar flare-interplanetary shock accelerated events occur on the order of a dozen times during a solar cycle. While such hybrid events are infrequent, they can be quite large.

The PPS system is designed to generate a solar proton flux distribution in space that will match the Earth-observed statistical average intensity-time profile, flux and time-of-maximum spectra found by spacecraft measurements to be associated with solar activity at a specific heliolongitude with respect to the Earth.

The solar proton flare event diagnostics of the 1970's and 1980's are identical to the fast CME

proxies of the 1990's. The concept of particle acceleration in the solar corona by fast CME's is still consistent with the fundamental parameters of the Proton Prediction system. It is assumed that the maximum possible flux will be encountered on the Archimedean spiral path leading from the solar active region. It is also assumed that there is a relation between the energy in the electromagnetic emission parameters and the proton flux observed in space. It is further assumed that there will be a heliolongitudinal gradient of particle intensity in space that decreases one order of magnitude per radian of angular separation for the most favorable propagation path. The particle flux intensity in space will be mapped in accordance with the Archimedean spiral configuration of the interplanetary magnetic field. The connection of the Earth to the solar active region via the interplanetary magnetic field is a controlling parameter in the prediction of how much solar particle flux will be received at the Earth.

The PPS system is designed to take many input parameters. The first available reports of intense radio or solar X-ray emissions, from onset to maximum, can be utilized for a quick prediction mode. This allows for a possible prediction of the solar proton event before the solar protons reach the Earth. Unfortunately, this quick predict mode based on peak flux data is also the least accurate. The PPS prediction accuracy essentially doubles when event integrated data are used for the input.

The input needed to specify the time and intensity of the solar flare source in the PPS can take two forms: (a) solar radio emissions observed by the USAF RSTN sites at 8800, 4995, 2695, 1415, 606 MHz or 10 cm (b) soft X-ray events observed by the GOES satellites in either the 0.5-4.0 or 1-8 Angstrom bands. The location of the solar flare is determined from H-alpha observations made by the USAF SOON sites. PPS contains an 'expert' mode enabling the user to override certain PPS default values used to classify the proton energy spectra at the Earth, but its use is NOT recommended unless the user has considerable experience in interpreting solar proton events.

The version of PPS implemented in AF-GEOSpace provides output showing the time dependence of proton fluxes in several differential and integral energy channels relevant to the GOES satellite. Also given are the time intervals for which the > 5 MeV, > 10 MeV and > 50 MeV integral proton fluxes, such as measured on the GOES satellites, are above the threshold value of 10 particles/($\text{cm}^2 \text{ s sr}$). The time and value of the peak response in each of the above channels during the solar proton event is estimated. Several user-specific quantities are also calculated including forecasts for the riometer absorption in Thule, Greenland, maximum radiation dosage for pilots in high-flying aircraft above the poles, and maximum radiation dosage to be expected both inside and outside a polar-orbiting space shuttle.

PPS Inputs

The PPS science module requires the following inputs:

Global Parameters: None

Data Type: The user can choose whether solar *Radio* emission data as measured by the USAF RSTN sites or solar *X-ray* emissions as measured by the GOES satellite are to be used to parameterize the solar flare.

Flux Type: The user can choose whether *Peak flux* or *Integrated flux* values are to be used to characterize the amplitude of the solar radio or X-ray emissions.

X-ray Data: If *X-ray* is chosen as the data type, the user chooses whether to use either the *0.5 - 4.0 Angstrom* or *1.0 - 8.0 Angstrom* bands.

- Radio Frequency:** If *Radio* is chosen as the data type, the user chooses here which fixed frequency band, centered at 8800, 4995, 2695, 1415, 606 MHz or 10cm, is to be used.
- Event onset time:** Depending on the choice of data type, the onset time of either the radio or X-ray event in the format MM/DD/YY HH:MM.
- Time of maximum:** Depending on the choice of data type, the time of the maximum amplitude of either the radio or X-ray event in the format MM/DD/YY HH:MM.
- Flare lat. (deg N):** The solar latitude, in degrees North, of the solar flare associated with either the X-ray or radio event. This information can be obtained from H-alpha observations by the USAF SOON sites. Degrees South are entered as negative numbers.
- Flare lon. (deg W):** The solar longitude, in degrees West, of the solar flare associated with the X-ray or radio event. This information can be obtained from H-alpha observations by the USAF SOON sites. Degrees East are entered as negative numbers.
- Use X-ray classification input?:** If the user has selected *X-ray* as the input data type and *Peak flux* as the flux type, the user can select here whether to use the standard X-ray event classification scheme to specify the magnitude of the peak.
- Peak class.:** If the user has selected to use the *X-ray* classification type to specify the peak magnitude of an X-ray event, the user inputs here the peak X-ray level measured by either the 0.5-4.0 or 1-8 Angstrom (depending on the X-ray band selected above) X-ray instrument on the GOES satellites. These values are entered with a classification letter and a numeric field. The usual X-ray event classification letters A, B, C, M, or X can be used with the numeric field consisting of 1-3 characters which may be digits or an optional decimal point. The numeric field multiplies the flux level. The range of allowed values is A1 through X99.
- Event amplitude:** The descriptor of this input box changes depending on what options for input data have been selected. The six character code at the beginning of the descriptor line summarizes the input and has the following format: AAANNB, where,
- AAA = XRY if X-ray has been selected as the input data type
RAD if Radio has been selected as the input data type
- NN = 54 if the 0.5-4.0 Angstrom X-ray data band has been chosen
18 if the 1.0-8.0 Angstrom X-ray data band has been chosen
14 if the 1415 MHz Radio Frequency has been chosen
26 if the 2695 MHz Radio Frequency has been chosen
49 if the 4995 MHz Radio Frequency has been chosen
88 if the 8800 MHz Radio Frequency has been chosen

B = P if the Peak flux has been chosen

I if the Integrated flux has been chosen

The remainder of the line plainly states the type of input data required and what units need to be used, that is,

Peak X-ray emission in units of ergs/cm²/s (if the X-ray classification option has not been selected).

Integrated X-ray emission in units of Joules/cm².

Peak Radio emission in Solar Flux Units ($=1.0 \times 10^{-22}$ W/m² Hz)

Integrated Radio emission in units of SFU-s

Amplitude data can be entered in the standard integer, real number, or exponential formats

Expert Mode: This mode allows the user to override certain PPS default input quantities, i.e., spectral slope, spectra type (differential or integral), flux normalization, time of flux maximum, and GOES energy channel.

Note: Use of the *Expert Mode* is NOT recommended unless the user has considerable experience in interpreting solar proton events.

The remainder of the buttons in the PPS environment window control various output options and are described below.

PPS Outputs

PPS returns a text message window containing the results of the model calculations and a summary of the input parameters. The model provides the following predictions:

- Maximum day polar riometer absorption at Thule, Greenland, in db, and the time that this maximum will occur in HH:MM (UT) MON DD. This prediction is valid if it is daytime at Thule (i.e., between 6:00 and 18:00 LOCAL Thule time) during the interval of the solar event. Note that ionospheric absorption is a function of the solar zenith angle.
- Maximum night polar riometer absorption at Thule, Greenland, in db, and the time that this maximum will occur in HH:MM (UT) MON DD. This prediction is valid if it is nighttime at Thule (i.e., between 18:00 and 6:00 LOCAL Thule time) during the interval of the solar event.
- Maximum dose rate expected at an altitude of 70,000 feet above the polar regions, in mRad/hr, and time this maximum will occur in HH:MM (UT) MON DD. This output can be used to estimate pilot dosages.
- Maximum dose rate expected at an altitude of 50,000 feet above the polar regions, in mRad/hr, and time this maximum will occur in HH:MM (UT) MON DD. This output can be used to estimate pilot dosages.
- Maximum dose rate above the polar regions at altitudes corresponding to typical space shuttle orbits (about 250 km). Dose rates in Rad/hr are given for both Extra Vehicular Activities (no shielding) and inside the shuttle behind 2 g/cm² of Aluminum shielding. The time of maxi-

mum is also given in HH:MM (UT) MON DD.

- The interval of time for which the > 5 MeV proton flux near Earth (e.g., as measured on the GOES satellites) will be above the threshold value of 10 particles/(cm² s sr) in the form MON DD HH:MM (UT, start time) - MON DD HH:MM (UT, end time). The maximum flux value, in particles/(cm² s sr), and the time of the maximum in HH:MM (UT) MON DD are given. Also estimated is the > 5 MeV fluence (= flux*time) for the duration of the event.
- The interval of time for which the > 10 MeV proton flux near Earth (e.g., as measured on the GOES satellites) will be above the threshold value of 10 particles/(cm² s sr) in the form MON DD HH:MM (UT, start time) - MON DD HH:MM (UT, end time). The maximum flux value, in particles/(cm² s sr), and the time of the maximum in HH:MM (UT) MON DD is given. Also estimated is the > 10 MeV fluence (= flux*time) for the duration of the event.
- The interval of time for which the > 50 MeV proton flux near Earth (e.g., as measured on the GOES satellites) will be above the threshold value of 10 particles/(cm² s sr) in the form MON DD HH:MM (UT, start time) - MON DD HH:MM (UT, end time). The maximum flux value, in particles/(cm² s sr), and the time of the maximum in HH:MM (UT) MON DD is given. Also estimated is the > 50 MeV fluence (= flux*time) for the duration of the event.

PPS also provides three plots selectable from buttons in the PPS Environment window:

- Diff Flux-GOES: Differential proton flux as a function of time at geosynchronous altitude for the energy ranges measured by the Space Environment Monitor on the GOES satellites, i.e., 1-4 MeV, 4-8 MeV, 8-16 MeV, and 16-215 MeV. The dotted red line corresponds to the threshold of 10 protons/(cm² s sr).
- Diff Flux-GWC: Differential proton flux as a function of time for the energy ranges 0.8-1.2 MeV, 4-6 MeV, 9-11 MeV, 14-16 MeV, and 49-51 MeV. The dotted red line corresponds to a threshold of 10 protons/(cm² s sr).
- Integ.Flux: Integral proton flux as a function of time at geosynchronous altitude for energy ranges measured by the Space Environment Monitor on the GOES satellites, i.e., at greater than 10, 30, 50, 100, and 500 MeV, respectively. The dotted red line corresponds to a threshold of 10 protons/(cm² s sr).

The following output options are also selectable from the PPS Environment window,

- Plot Options: This widget allows one to set the Y-axis min, max and number of ticks for the plots. The *Auto* button gives (rounded) limits spanning the data and the default is set at -5 to 5 (log10).
- Display Text: Clicking this button will display the text output window if it has been closed.

The SEEMAPS Science Module

Model Name:	SEEMAPS
Version:	September 1998
Developer:	Radex, Inc.
Reference:	Mullen, E.G., G. Ginet, M.S. Gussenhoven, and D. Madden, SEE Relative Probability Maps for Space Operations, <i>IEEE Trans. Nuc. Sci.</i> , 45 , 2954-2963 (1998)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

SEEMAPS Overview

The Single Event Effects Maps (SEEMAPS) are a geographically tagged database of the relative probability for satellite on-board micro-electronics to suffer single event effects in the low Earth orbit (LEO) regime. Until now, the most readily accessible and usable means to determine the SEE risk, either for design or operations, was by using proton contours from the NASA Particle Maps [Sawyer and Vette, NSSCE 76-06, NASA/GSFC, Greenbelt, MD, 1976]. However, both data and our physical understanding of the Earth's magnetic field movement indicate that the location of the energetic proton belts has changed significantly since these maps were made in 1970.

The SEEMAPS are an improved model for determining relative risk assessment from SEEs in the near-Earth space in the present epoch based on data taken from the Advanced Photovoltaic and Electronics (APEX) and Combined Radiation and Release Experiment (CRRES) satellites. The data cover the period from July 1990 to October 1991 (CRRES, near solar maximum) and from August 1994 to May 1996 (APEX, near solar minimum). A comparison of radiation dose from the two spacecraft as well as from the Defense Meteorological Satellite Program (DMSP) F7 spacecraft for the previous solar minimum period (1984-1987) is given by Gussenhoven *et al.* [*IEEE Trans. Nucl. Sci.*, **43**, 2035, 1995]. This work showed that there was a small variation in proton dose over the last solar cycle. The fact that the change was small for inner belt protons gives us reason to believe that the combined APEX and CRRES databases give a near worst-case model (solar minimum) useful for orbit trade-off studies and mission operations planning.

An excerpt from Mullen *et al.* [1998] describes the basic SEEMAP construction and capability:

“Normalized flux and dose data for protons with energies >50 MeV are used to produce contour maps of relative probabilities of experiencing SEEs in the Earth's inner radiation belt. The data were taken on the APEX and CRRES satellites. To make the maps, the data are averaged in 3° x 3° bins in geographic latitude and longitude, and in 50 km steps in altitude. All geographic longitudes and latitudes less than or equal to 70° are covered. The altitude range extends from 350 km to 14,000 km. This geographic range includes the complete region of inner belt > 50 MeV protons, except in the South Atlantic Anomaly region below 350 km. The maps easily locate regions of high risk for SEEs and are designed primarily for use in space mission planning and operations. The data base includes the added proton peak following the March 1991 magnetic storm, but does not include SEE probabilities in the polar cap region associated with high energy solar particle events.”

Though the SEE relative probability maps are constructed from data sets of flux rates corresponding to > 50 MeV particles depositing energy in the APEX and CRRES dosimeters, these flux rates were carefully compared with both the >50 MeV dose rate and single event upsets measured in a solid state tape recorder on-board APEX. The correlation was found to be good. Relative probabilities were computed by dividing the dosimeter flux rate by a normalization factor of 2360.45, which gives relative probability values in the range of 0 to 5.5. This factor was based on APEX measurements as explained in *Mullen et al.* [1998]:

“... a normalization factor is calculated from the average flux rate for the HILET A Dome 4 [dosimeter] between the altitudes of 1,000 and 1,050 km for data points between 1,000 and 5,000 counts/s. This altitude and count rate level were chosen because they are near the middle of the altitude range, have sufficient points for good statistics, are the highest count rates for the altitude range, and are most easily remembered (>1000 counts/s at 1000 km).”

The SEEMAPS should be most useful for a space system operator to a) tell when and how the spacecraft enters regions of high intensity (like the SAA) and the time spent in the region, b) estimate how many upsets to expect in every region by keeping track of when and where upsets occur and then using the normalization factors, and c) determine the factor to go from normalized values to upsets/device/unit time/region once the upset data base is large enough.

SEEMAPS Inputs

The SEEMAPS Science Module requires the user to specify the following information to determine which data set to use in mapping the data,

- | | |
|----------------|--|
| Altitude bins: | The altitude bins parameter determines which of the proton flux data sets corresponding to over two hundred bins between 350 and 15,000 km is to be considered. If the <i>All</i> toggle is on, all of the bins are loaded. |
| Activity: | The activity parameter specifies whether the <i>Quiet</i> (obtained before the 24 March 1991 storm) or <i>Active</i> (obtained after the 24 March 1991 storm) proton flux data sets are to be used. This parameter is the same as that used in the CRRESPRO module (see the CRRESPRO Science Module documentation in this manual). |

SEEMAPS Outputs

The SEEMAPS Science Module returns a 3D Gridded Data Set of the relative probability value (*RELATIVE PROB*) for the selected altitude bin (or all bins) and activity level.

The STOA Science Module

Model Name:	Shock Time of Arrival (STOA)
Version:	1.0 (1987)
Developer:	D. Smart, Air Force Research Laboratory; M. Dryer and L.D. Lewis, NOAA Space Environment Center
References:	Smart, D.F., M.A. Shea, M. Dryer, A. Quintana, L.C. Gentile and A.A. Bathurst, Estimating the Arrival Time of Solar - Flare - Initiated Shocks by Considering them to be Blast Waves Riding over the Solar Wind, in Simon, P.A., G. Heckman and M.A. Shea, Eds., <i>Solar-Terrestrial Predictions: Proceedings of a Workshop at Meudon</i> , France, June 18-22, 1984, U.S. Government Printing Office, Washington, D.C., pp. 471-481 (1986) Smart, D.F. and M.A. Shea, A Simplified Model for Timing the Arrival of Solar Flare-Initiated Shocks, <i>J. Geophys. Res.</i> , 90 , 183-190 (1985)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

STOA Overview

The sudden release of energy into the solar atmosphere will create a shock wave. The STOA model applies the Sedov similarity theory to the general characteristics of the interplanetary medium [Sedov, *Similarity and Dimensional Methods in Mechanics*, Academic Press, New York, 1959]. The STOA concept is a blast wave propagating over the pre-existing solar wind. When an interplanetary shock has been generated by a solar disturbance, the STOA science module can be invoked to predict the arrival time of the shock at the Earth or at another ecliptic plane location. We refer to the shock-producing solar events, whether they be coronal mass ejections or solar flares, as "solar flares," because the model was originally developed assuming that solar flares were the drivers for the interplanetary shocks.

The STOA shock speed profile as a function of radial distance has been found to compare favorably with 2 1/2-D MHD simulations of interplanetary shocks propagating along the flare-radial direction, for test cases where the initial shock speeds were identical (see review by Wu [*Space Science Reviews*, **32**, 115, 1982]). The MHD models simulate the behavior of solar flare initiated shock waves propagating through interplanetary space.

The STOA arrival time is calculated by modeling the shock propagation in two phases: a "driven" phase and a "blast" phase. During the initial driven phase the shock is assumed to be driven by the solar flare. It is assumed that the shock disturbance originates in the solar atmosphere at a distance $R=0.007$ AU from the center of the Sun. A constant speed is assigned to this driven phase and is assumed to be given by the frequency drift rate of the Type II radio burst with the onset time coinciding with the beginning of the burst. The end time of the driven phase is the time when the soft X-ray emission power has decayed to half of the log of the maximum flux above the pre-event background. The radial distance covered by the driven phase is given by the product of the Type II drift speed multiplied by the driver time.

The distance from the Sun's center to the end point of the driven phase in a flare radial direction is

$$R_d = 0.007 + V_d T_d \text{ (AU)}.$$

The initial condition simulated by STOA is a shock front that may extend across a major part of the Sun, with a shock front speed profile given by

$$V_\theta = V_r f \quad \text{with} \quad f = (\cos(\theta) + 1)/2$$

where θ is the angle measured at the center of the Sun between the flare radial direction and any other radial direction. The driven distance at an angle θ is

$$R_{d\theta} = 0.007 + f V_d T_d \text{ (AU)}.$$

After the driven phase it is assumed that the propagation of the disturbance through the interplanetary medium can be described as a blast wave superimposed on the preexisting solar wind. Only the shock front or leading edge of the blast wave is considered in this model; no information is provided on the structure of the shock wave. The average radial blast wave speed is obtained by integrating the blast wave equation in the flare radial direction.

In the interplanetary medium it is assumed that the density is proportional to the inverse square of the distance R from the center of the Sun, and that the blast wave speed decreases as $R^{-1/2}$. The average radial blast wave speed is projected onto the Sun-observer direction using the foreshortening factor described earlier. It is assumed that the speed anisotropy adopted for the driven phase persists through the blast phase. Finally, the average speed of the disturbance during the blast phase is the average blast wave speed in the observer direction added vectorially to the average solar wind speed. For simplicity, it is assumed that the solar wind is moving radially away from the Sun at a constant speed. In a flare radial direction, the wave speed is

$$V = B R^{-1/2} + V_{sw} \quad \text{with constant } B = V_d R_d^{1/2}.$$

In a non flare-radial direction the shape factor is involved and the wave speed is

$$V_\theta = f B R^{-1/2} + V_{sw} \quad \text{with } V_\theta = dR/dt,$$

which is integrated from $R = R_{d\theta}$ to obtain the shock's propagation time to the desired radius R .

The predicted shock arrival time is simply the sum of the initial Type II burst time, the driven phase duration and the travel time of the disturbance through the interplanetary medium. As the blast wave loses energy during its propagation through the interplanetary medium, the shock speed decays to the magneto-acoustic speed. The program computes the sonic Mach number and Alfvén speed in interplanetary space, using simple approximations for interplanetary plasma density, temperature and magnetic field as a function of distance from the Sun, and derives the magneto-acoustic Mach number of the shock. If this number is less than Mach 1 at the Earth or other selected observation point, no shock is predicted to arrive.

The STOA documentation and associated references suggest that shocks which are capable of propagating to 1 AU are likely to be associated with “big flares”. The criteria for identifying a big flare are not, however, clearly established. There is an indication, based on the original testing of the program, that the better STOA predictions are associated with “long duration soft X-ray events”. This means a decay time T_d of one hour or more, together with a velocity V_d equal or greater than 1000 km/s. Other diagnostics of shock generation and propagation into the solar corona may be coronal mass ejection information and forecaster judgement.

STOA Inputs

The STOA science module requires the following inputs:

Global Parameters: None

Specify Event Duration: The user can choose to specify either the *Stop Time* of the event, the *Duration* of the event, or have the event duration estimated from inputs of the associated GOES soft *X-ray Levels*.

Observer Location: The observer location can be designated as *Earth* or *Specified* by the user. The latter choice prompts for the user to enter the observer distance (*Obs. Distance*), offset angle (*Obs. Offset Angle*), and name (*Obs. Name*) in the lowest three text boxes on the right side of the window as described below.

Event onset time: Time of onset of Type II radio burst from USAF RSTN site in the format MM/DD/YY HH:MM.

Event end time: When *Stop Time* is selected to specify the event duration, the user enters the event end time in the format MM/DD/YY HH:MM. The end time of the shock driver must not be earlier than the Type II event onset time. The shock driver time must be less than 7 days (168 hours). Shock driver durations are typically a fraction of a day. In this case, GOES satellite X-ray levels are not used to estimate the event duration.

Event duration: When *Duration* is selected to specify event duration the user enters the event duration in hours. The shock driver time must be < 7 days (168 hours). Shock driver durations are typically a fraction of a day. In this case, GOES satellite X-ray levels are not used to estimate the event duration.

Backg. Class: When *X-ray Levels* is selected to specify the event duration, the user enters the background X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite before the event occurred. This value is entered with a classification letter and a numeric field. The usual X-ray event classification letters A, B, C, M, or X can be used with the numeric field consisting of 1-3 characters which may be digits or an optional decimal point. The numeric field multiplies the flux level. The range of allowed values is A1 through X99.

Peak. Class: When *X-ray Levels* is selected to specify the event duration, the user inputs here the peak X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite during the X-ray event. The format is the standard X-ray event classification scheme as explained above. After entering this value the user should click in the *Decay time* box and the level XN.N corresponding to 1/2 log of the peak signal will be displayed next to that box.

Decay time, level XN.N: When *X-ray Levels* is selected to specify the event duration the user enters the time in the format MM/DD/YY HH:MM at which the X-ray level measured by the 1-8 Angstrom X-ray instrument on a GOES satellite during the X-ray event decays to the level XN.N. The *level XN.N* is calculated from the *Backg. Class.* and *Peak. Class.* Of course, this time will occur after the peak of the X-ray event.

- Type II speed(km/s): The Type II drift speed in km/s calculated by the USAF RSTN network and select other radiotelescope sites from observations of Type II radio bursts. This value must be greater than 0 and less than 10000 km/s.
- Flare lat. (deg N): The solar latitude, between +90° and -90° North, of the solar flare associated with the Type II radio burst. This information can be obtained from H-alpha observations by the USAF SOON or other optical sites or from X-ray images. Degrees South are entered as negative numbers.
- Flare lon. (deg W): The solar longitude, between +180° and -180° West, of the solar flare associated with the Type II radio burst. This information can be obtained from H-alpha observations by the USAF SOON or other optical sites or from X-ray images. Degrees East are entered as negative numbers. Longitudes greater than +/- 90° from the direction of the observer may not be realistic.
- Solar wind speed (km/s): The solar wind speed must be positive and less than 1000 km/s.
- Obs. Distance: When the *Observer Location* is to be *Specified* the user enters the observer distance in AU. It must be greater than 0.007 AU and less than 100 AU. Note that observer distances less than 0.2 AU or greater than 50 AU are unrealistic. This condition is not detected until all of the data have been entered because it depends on several data entries.
- Obs. Offset Angle: When the *Observer Location* is to be *Specified* the user enters the observer offset angle in degrees. It is the offset angle from the Sun-Earth line, from -360° to +360°, and is measured in the ecliptic plane, in the same sense as the longitude of the solar flare: west is positive, east is negative.
- Obs. Name: When the *Observer Location* is to be *Specified* the user enters the observer name as a 5 character alphanumeric value. If this field is left blank STOA uses the Earth as the default observer.
- Display Text: Clicking this button will display the text output window if currently closed.

STOA Outputs

STOA returns a text message window containing the results of the model calculations and a summary of the input parameters. The model outputs are:

- Magneto-acoustic Mach number and arrival time of shock at observation point
- Total propagation time of shock in hours and minutes
- Type II onset time
- X-ray or other event end time
- Driver duration time in hours
- Type II speed in km/s
- Solar flare latitude and longitude
- Solar wind speed
- Distance from Sun to observer (e.g., Earth) in AU

The WBMOD Science Module

Model Name: Wide-Band Model (WBMOD)
Version: 13.04 (24 January 1996)
Developer: Northwest Research Associates, Defense Nuclear Agency, and Air Force Research Laboratory
References: Secan, J.A., and R.M. Bussey, An Improved Model of High-Latitude F-Region Scintillation (WBMOD Version 13), *PL-TR-94-2254* (1994), ADA 288558

Note: It is recommended that AF-GEOSpace users read and understand the original model documentation and descriptive articles before using the models.

WBMOD Overview

WBMOD is a climatological model for ionospheric scintillation. Because WBMOD is a climatological model, it is best suited for long-range planning and engineering studies. It is not as well suited for daily planning or operations. WBMOD specifies S4, 95th percentile fades, and other scintillation parameters for trans-ionospheric radio-wave propagation paths given: a location on the globe, a satellite above 100 km altitude, an RF frequency above 100 MHz, and several geophysical activity indices.

WBMOD Inputs

The WBMOD science module requires the following inputs,

Global Parameters: Day, UT, Kp, and SSN (note: Year, F10.7 and Ap are not used).
Propagation: Specifies whether *1-Way* or *2-Way* propagation effects should be calculated. For the *2-Way* option, the user must also input the following,
Up/Dn Link Corr: The correlation between up-link and down-link signals.
For up/down links between the same transmitter and receiver, this parameter should be set to 1; for bi-static links with spatially separated receivers set it to 0.
In-situ Vd: F region plasma drifts; calculated by WBMOD using models when the *Model* option is selected or specified explicitly by the user when the *Input* option is selected. When the *Input* option is selected the user must specify the following,
Vd, north (m/s): Northward F region plasma drift in meters/second.
Vd, east (m/s): Eastward F region plasma drift in meters/second.
Vd, down (m/s): Downward F region plasma drift in meters/second.
Step: Option to step (move) the receiver (*Rcvr*) or the transmitter (*Trans*). Normally the transmitter is a satellite and the receiver is ground-based. Moving the receiver or satellite maps out regions of scintillation. We recommend that the user use the step receiver mode. This mode will produce a map that is easiest to interpret.

Note: In the step transmitter mode, *Trans*, data is for scintillation on the ray-path from the satellite to the receiver and plotted at the sub-satellite point. This display location is not the ionospheric location where the scintillation occurred. Similarly, for the step receiver mode, *Rcvr*, the data will be plotted at the receiver location, not the ionospheric location where scintillation occurred.

EP Boundary:	The location of the equatorward boundary of auroral precipitation may be calculated by WBMOD in the following ways,
Eff. Kp:	<p>An effective Kp calculated explicitly from a DMSP observation of the equatorward boundary in magnetic latitude and local time is used. If selected, the following must be specified,</p> <p>Effective Kp: The effective Kp derived from the equatorward boundary location observed by a DMSP SSJ/4 sensor (different from the Global Parameter Kp).</p>
Explicit:	<p>EP boundary locations are specified directly by the user. If selected, the following must be specified,</p> <p>EP Bndry MLAT: The magnetic latitude of an equatorward boundary crossing observed by the SSJ/4 sensor on DMSP.</p> <p>EP Bndry LT: The local time of an equatorward boundary crossing observed by the SSJ/4 sensor on DMSP. This must be consistent with the <i>EP Bndry MLAT</i> entered above.</p>
Use Kp:	Kp from the Global Parameters is used.
Output:	WBMOD output can be determined by two different calculation methods,
Percentile:	<p>WBMOD computes the S4 scintillation index and other parameters for user defined climatological percentile, i.e., level of disturbance. If selected, the following must be specified,</p> <p>Percentile(0.0-1.0): This percentile selects the level of disturbance, i.e., the S4 that corresponds to this percentile. Typical procedures use 90th percentile (the 10th worst disturbance level).</p>
Threshold:	<p>WBMOD computes the percentage of time that either the S4 or phase index exceeds a certain threshold value. If selected, the following must be specified,</p> <p>Thresh. Param: Either the <i>S4</i> or <i>Phase</i> index can be selected for threshold parameterization (toggle).</p> <p>Threshold: The threshold level is dimensionless for <i>S4</i>, ranging from 0.0 to 1.2, and is in radians for <i>Phase</i>.</p>

Trans. Freq (MHz):	Specifies transmitter frequency for scintillation calculation in MHz.
Trans.Alt (km):	Specifies altitude of transmitter (satellite) in km.
Fixed End Lat:	Geographic latitude in degrees of transmitter or receiver, depending on which is fixed as specified by <i>Step</i> option.
Fixed End Lon:	Geographic longitude in degrees of transmitter or receiver, depending on which is fixed as specified by <i>Step</i> option.
Phase Stability (s):	Length of time in seconds over which phase stability is required for operational system. For communication applications this parameter approaches zero and is not critical. For applications involving coherent data integration (e.g., radar) this parameter should be set equal to the integration period.
Kp@Local Sunset:	The value of Kp at the time of last sunset at the ground-based transmitter or receiver location. A value of -1 defaults to the value of Kp used in the EP Boundary computation.

WBMOD Outputs

The WBMOD science module returns 2D Gridded Data Sets. We recommend displaying output in 2D plots using the COORD-SLICE graphical object. AF-GEOSpace will then display a spatial distribution (map) for the following parameters:

95%tile FADE:	The 95th percentile fade depth of the signal intensity (decibels). Don't confuse this percentile with the climatological percentile input to WBMOD. For example, if the user selected a 90th percentile climatology, then this output represents the 5th most severe fade on the 10th most disturbed day. Fades are plotted as positive values.
S4:	The S4 scintillation index, a normalized standard deviation of the signal intensity (dimensionless).
STDDEV PHASE:	The standard deviation of the phase (radians). Also known as sigma-phi.
STDDEV LOG(I):	The standard deviation of the log of the intensity (decibels).
%Time:	The percentage of time that <i>S4</i> or <i>Phase</i> exceeds a specified threshold level for given conditions (%). This parameter is meaningful only when the model has been run in <i>Threshold</i> mode.

Application Modules

Application modules provide orbit creation/prediction, dataset integration along orbits, magnetic field model generation, and access to specialized ionospheric ray-tracing, graphics, and scintillation products. The application modules are accessed through the application manager which becomes visible when the *Application* button under the Environment's Modules pulldown menu is activated. The application manager consists of two lists - *Available Application Modules* and *Active Application Modules*. *Available Application Modules* are the modules that are currently supported by AF-GEOSpace. *Active Application Modules* are modules that have been created and used by the AF-GEOSpace user during the current session.

When initially accessed, the application manager will show a list of applications under *Available Application Modules*. Since no applications have yet been created, the *Active Application Modules* list will be empty.

Currently, the following applications are supported by AF-GEOSpace:

- **APEXRAD-APP:** Advanced Photovoltaic and Electronics Experiments (APEX) radiation dose model calculates expected accumulated yearly dose (in units of rads silicon/year) for four thicknesses of aluminum shielding during four levels of magnetic activity. Best for orbits with apogees less than 2500 km (see the CRRESRAD-APP for higher altitudes).
- **BFIELD-APP:** The B-Field application allows the generation of datasets representing the magnetic field in the near-Earth space environment. A variety of internal (dipole, IGRF) and external [Olson and Pfitzer 1977; Hilmer and Voigt 1995; Tsyganenko 1987; Tsyganenko 1989] field models are used to generate gridded data set, field lines, and flux tubes.
- **CRRESELE-APP:** Combined Radiation and Release Effects Satellite (CRRES) electron flux model specifies the location and intensity of electron omnidirectional fluence (integral and differential) over the energy range 0.5-6.6 MeV for a range of geomagnetic activity levels.
- **CRRESPRO-APP:** Combined Radiation and Release Effects Satellite (CRRES) proton flux model calculates proton omnidirectional fluence (integral and differential) over the range 1-100 MeV for user specified orbits and quiet, active, or average geophysical activity levels.
- **CRRESRAD-APP:** Combined Radiation and Release Effects Satellite (CRRES) space radiation dose model calculates expected satellite dose accumulation behind four different thicknesses of aluminum shielding for user-specified orbits for active or quiet geophysical activity levels.
- **IMAS-APP:** Accesses the Ionosphere Modeling/Analysis System containing specific graphics and ray-trace models to use with data sets generated by the Parameterized Ionosphere Model (PIM).
- **LET-APP:** Calculates the linear energy transfer (LET) spectrum and its associated single event upset (SEU) rate in a microelectronic device resulting from the penetration of energetic space particles. Effects from both cosmic rays and the trapped protons are estimated by using

the CHIME and CRRESPRO models as inputs.

- **SATEL-APP:** Calculates orbital trajectories for satellites from a variety of user specified orbital element input sets. Also calculates properties of associated satellite detector cones and ground-to-satellite links
- **WBPROD-APP:** Gives a 24hr WBMOD climatology prediction of the dB fade levels due to ionospheric scintillation effects for specific ground-to-satellite communication links.

Running Application Modules

To run an *Application*, click the mouse on the desired choice under the *Available Application Modules*. For example, to create a new version of the CRRESELE-APP module, click the mouse on *CRRESELE-APP* in the *Available Application Modules* list. Choosing an application will do two things: first, the choice is added to the *Active Application Modules* list; second, the options associated with the chosen application will appear below the application manager windows. In general, each application will have a different Environment Window representing the inputs specific to the application.

The bottom section of the application window is the same for all applications. It consists of a status window and buttons for running and deleting the application, a button to access the grid tool, and a button to allow the application data to be saved to a file.

- **Model Status:** The *Model Status* box provides a brief informational message regarding the current state of the application. Upon creation, the status will be "MODEL INITIALIZED". If the application is up-to-date and ready for use by other modules, the message will indicate "MODEL IS READY AND UP TO DATE". If parameters have been changed since last running the application, the status box will indicate "PARAMETERS MAY HAVE CHANGED". Other informational messages may also be displayed depending on the specific application. A scroll feature is provided for reading longer messages.
- **Run Model:** After setting all of the inputs as desired, the application may be executed by activating the *Run Model* button. An informational box will appear indicating the application is running. When completed, the informational box will disappear. At this point, the data generated by the application is available for use by graphics modules.
- **Delete Model:** If the application is no longer needed, it may be deleted by selecting the *Delete Model* button.
- **Grid Tool:** Some applications calculate data on a grid. The Grid Tool allows the user to choose the parameters associated with the calculation grid. Activating the *Grid Tool* button will open the Grid Setup window.
- **Save To File:** Data from the application can be stored to disk in several formats. Activating the *Save To File* button opens a window allowing options on formats and variable choices to be set. More information on the *Save to File* options are available in the Miscellaneous Topics section of this manual.

The APEXRAD-APP Module

Model Name:	APEXRAD
Version:	15 September 1997
Developer:	Air Force Research Laboratory
References:	<p>Bell, J.T., and M.S. Gussenhoven, APEXRAD Documentation, <i>PL-TR-97-2117</i> (1997), ADA 331633</p> <p>Gussenhoven, M.S., E.G. Mullen, D.A. Hardy, D. Madden, E. Holeman, D. Delorey, and F. Hanser, Low Altitude Edge of the Inner Radiation Belt: Dose Models from the APEX Satellite, <i>IEEE Trans. Nucl. Sci.</i>, 42, 2035 (1995)</p> <p>Gussenhoven, M.S., E.G. Mullen, J.T. Bell, D. Madden, and E. Holeman, APEXRAD: Low Altitude Orbit Dose as a Function of Inclination, Magnetic Activity and Solar Cycle, <i>IEEE Trans. Nucl. Sci.</i>, 44, 2161, (1997)</p> <p>Mullen, E.G., M.S. Gussenhoven, J.T. Bell, D. Madden, E. Holeman, and D. Delorey, Low Altitude Dose Measurements from APEX, CRRES, and DMSP, <i>Advances in Space Res.</i>, 21, 1651, (1997)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

APEXRAD-APP Overview

The APEXRAD application and science modules are a port of the PC program APEXRAD developed and released by the Air Force Research Laboratory. More information can be found in the APEXRAD Science Module section of this document.

The APEXRAD-APP module calculates satellite radiation dose accumulations behind four different thicknesses of aluminum (either slab or hemisphere) for user-specified orbits. Dose accumulation is predicted using empirical dose rate models created from data measured on the Advanced Photovoltaic and Electronics Experiment (APEX) which flew in a 362 x 2544 km elliptical orbit inclined at 70 degrees. These dose models have a higher position resolution at low altitudes than the previously released CRRESRAD models. The APEXRAD models give dose rates averaged over the entire APEX mission and for four different levels of magnetic disturbance, based on a 15 day (offset by 1 day) running average of the linear geomagnetic activity index A_p . APEXRAD is best applied to orbits with apogees less than 2500 km, perigees greater than 350 km, inclinations less than 60 degrees and for times during solar cycle minimum. It can be useful for orbits with higher inclinations or lower perigees, but the user must account for any dose that may be received outside the region covered by the model. For higher altitude orbits the use of CRRESRAD is recommended.

Note: The APEXRAD science module need NOT be run before running APEXRAD-APP.

APEXRAD-APP Inputs

The inputs to the APEXRAD-APP module are the orbit elements needed to calculate the satellite orbit. The Environment Window for the APEXRAD-APP module is the same as that for the

SATEL-APP module (see the SATEL-APP Module documentation section for details).

APEXRAD-APP Outputs

The APEXRAD-APP module generates a return text window which can be saved to a file. Included in the text are the orbit elements and tables of the accumulated yearly dose (in units of rads silicon/yr) for all four thicknesses of aluminum shielding during four levels of magnetic activity. Also generated is a 1D Gridded Data Set giving the position of the satellite as a function of time. That 1D data can be written to a file by selecting the *Save to File* button, choosing variables from the *Output File* window, and clicking the *Save...* button.

The BFIELD-APP Module

Model Name:	BFGEOS
Version:	30 May 1997
Developer:	Air Force Research Laboratory
References:	<p>Hilmer, R.V., and G.-H. Voigt, A Magnetospheric Magnetic Field Model with Flexible Current Systems Driven by Independent Physical Parameters, <i>J. Geophys. Res.</i>, 100, 5613 (1995)</p> <p>Olson, W.P., and K.A. Pfitzer, A Quantitative Model of the Magnetospheric Magnetic Field, <i>J. Geophys. Res.</i>, 79, 3739 (1974)</p> <p>Olson, W.P., and K.A. Pfitzer, Magnetospheric Magnetic Field Modeling, Annual Scientific Report, Air Force Office of Scientific Research contract F44620-75-C-0033, McDonnell Douglas Astronautics Co., Huntington Beach, CA (1977)</p> <p>Pfitzer, K.A., Improved Models of the Inner and Outer Radiation Belts, Scientific Report No. 1, <i>PL-TR-91-2187</i>, Phillips Laboratory, Hanscom AFB, MA (1991), ADA 242579</p> <p>Tsyganenko, N.A., Global Quantitative Models of the Geomagnetic Field in the Cislunar Magnetosphere for Different Disturbance Levels, <i>Planet. Space Sci.</i>, 35, 1347-1358 (1987)</p> <p>Tsyganenko, N.A., A Magnetospheric Magnetic Field Model with a Warped Tail Current Sheet, <i>Planet. Space Sci.</i>, 37, 5-20 (1989)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

BFIELD-APP Overview

The B-Field application generates maps of the magnetic field in the near-Earth space environment. It can be used to generate gridded data sets of magnetic field magnitudes, to trace field lines and to construct flux tubes. The application code was written by Robert V. Hilmer of AFRL.

B-FIELD Inputs

Inputs to the BFIELD-APP are needed to specify which type of data set to generate and which field models to implement.

The *Generate* section specifies the data sets to be generated when the B-FIELD application is run. The user may choose any combination of data set choices.

Gridded Data: Choosing this option generates magnetic field GSM components and magnitude at each point on the grid specified under the *Grid Tool*. This option is useful for generating slices or isocontours at given magnetic field strengths.

MLAT Field Lines: Choosing this option generates field lines emanating from a constant (dipole) magnetic latitude. The user species the magnetic latitude, mini-

imum magnetic local time, maximum magnetic local time (all at one Earth radius), and the number of local time steps in the MLAT Field Line Inputs section. This option is useful for visualizing the shape of the magnetic field.

MLT Field Lines: Choosing this option generates field lines starting at a constant magnetic local time. The user species the magnetic local time, minimum magnetic latitude, maximum magnetic latitude (all at one Earth radius) and the number of latitude steps in the MLT Field Line Inputs section. This option is useful for visualizing magnetic field lines originating from constant magnetic local time.

Flux Tube: Choosing this option generates field lines representing a flux tube. The user specifies either the geographic (latitude, longitude, altitude) or magnetic (MLAT, MLT, Radius) coordinates of the center of the footprint of the flux tube, a diameter and the number of field lines to generate in the Flux Tube Inputs section. If a single field line is requested or the diameter is zero then a single field line is constructed anchored at the footprint center. Magnetic dipole coordinates are also available.

The *Internal B-Field* section allows the user to specify which model to use for the Earth's internal magnetic field. The options are:

Dipole: An Earth centered dipole field with the tilt determined by UT, Julian day, and year. The equatorial surface field is approximately 30750 nT.

IGRF(1945-2000): The International Geomagnetic Reference Field. The coefficient set is chosen according to the time between the first day of 1945 and the last day of 2000. Code source: National Space Sciences Data Center (NSSDC).

Fast IGRF: A computationally faster truncated version of the IGRF field developed by Pfitzer (1991). The typical speed advantage is 7 to 8 times while the output differs from that of the full IGRF routine by no more than 0.1 nT.

The *External B-Field* section allows the user to specify which model to use for external contributions to the magnetic field. The options are:

None: No external field model is used.

Hilmer-Voigt: The external field model developed by *Hilmer and Voigt* [1995] is applied. Choosing this option requires additional inputs to be specified in the Hilmer-Voigt Options window that appears upon selection.

Olson-Pfitzer: The external field model developed by *Olson and Pfitzer* [1977] is applied.

Tsyganenko '89: The external field model developed by *Tsyganenko* [1989] is applied. There are two model versions: (1) The Kp driven model uses the Kp index from the *Global Parameters* section of the *Environments* window and (2) the AE driven model requires an AE range to be selected from the *Tsyganenko '89 Options Window*. Code source: NSSDC.

Tsyganenko '87: The external field model developed by *Tsyganenko* [1987] is applied using the "long" warped tail with no aberration. The Kp index is input from the

Global Parameters section of the *Environment Window*.
Code source: NSSDC.

The *MLAT Field Line Inputs* section allows the user to specify the parameters needed if the *MLAT Field Lines* option has been chosen. The inputs required to specify the field lines are:

- MLAT: The constant magnetic latitude (dipole) specified in degrees from which to trace field lines.
- MLT0, MLT1: The minimum and maximum magnetic local times specified in hours. Field lines will be traced at magnetic local times between *MLT0* and *MLT1*.
- Steps: The number of field lines to trace ($= \text{Steps} + 1$). This specifies the number of field lines to trace from *MLT0* to *MLT1*. Hence, field lines will be traced at $MLT = MLT0 + i * (MLT1 - MLT0) / \text{Steps}$ where $i = 0$ to *Steps*

The *MLT Field Line Inputs* section allows the user to specify the parameters needed if the *MLT Field Lines* option has been chosen. The inputs required to specify the field lines are:

- MLT The constant magnetic local time specified in hours from which to trace field lines.
- MLAT0, MLAT1 The minimum and maximum magnetic latitude (dipole) specified in degrees. Field lines will be traced at magnetic latitudes from *MLT0* to *MLT1*.
- Steps The number of field lines to trace ($= \text{Steps} + 1$). This specifies the number of field lines to trace from *MLAT0* to *MLAT1*. Hence, field lines will be traced at $MLAT = MLAT0 + i * (MLAT1 - MLAT0) / \text{Steps}$ where $i = 0$ to *Steps*

The *Flux Tube Inputs* section allows the user to specify the parameters needed if the *Flux Tube* has been chosen. Either *Geographic* or *Magnetic* coordinates can be selected by clicking the appropriate button. The inputs required to specify the flux tube are:

- Lat, Long, Alt: The geographic latitude, longitude and altitude of the center of the flux tube. Latitude and Longitude are input in degrees. Altitude is specified in kilometers above the Earth's surface.
- MLAT, MLT, Rad: The magnetic latitude, local time and geocentric radius of the center of the flux tube. *MLAT* is specified in degrees, *MLT* is specified in hours, and *Rad* is specified in Earth radii.
- Diam: The diameter of the flux tube specified in kilometers for geocentric coordinates and degrees for geomagnetic coordinates. The edges of the flux tube are specified at the same altitude(radius) as the center. If *Diam* = 0 then a single field line is drawn from *Lat, Long, Alt* or *MLAT, MLT, Rad* location.
- Steps: The number of field lines to generate to represent the flux tube. The field lines will be traced from the boundary of a circle with diameter *Diam* centered at *Lat, Long, Alt*. If *Steps* = 1 then a single field line is drawn from *Lat, Long, Alt* or *MLAT, MLT, Rad* location.

Hilmer-Voigt Inputs

If the *Hilmer-Voigt External Field* is chosen, a popup window appears requesting further inputs. Several different input modes are available for the Hilmer-Voigt model,

Kp Only: For this case, only the Environment window global Kp is used to drive the model. Note that the Hilmer-Voigt model in Kp only mode only accepts Kp as an integer between 0 and 9. AF-GEOSpace will automatically convert the global Kp to an integer in this range. The value used will be displayed in the label next to *Kp Only*.

Standoff, Dst, Equat.Edge: The user must choose from discrete values of the standoff distance, the *Dst* value, and the equatorward edge of the diffuse aurora at midnight. Choosing this input will sensitize the inputs at the right side of the Hilmer-Voigt '95 options window.

Vacuum Configuration: For this mode, only the standoff distance needs to be specified. The standoff input box will be sensitized if this input mode is chosen. There are no restrictions for standoff distance (other than Standoff > 0) in this mode.

Combinations of input boxes at the right side of the Hilmer-Voigt '95 options window will be available according to the input mode setting. These boxes allow inputs of Dst, Equator Edge of the diffuse aurora at midnight and standoff distance to be selected. Because configurations representing all permutations of the Hilmer-Voigt input options do not exist (many are unphysical), the model status window will show the actual inputs used. If the parameters listed in the status window differ from those selected, then a configuration substitution has been made internally.

Dst: The value of *Dst* to use for the model. Used only in *Standoff, Dst, Equatorward Edge* input mode. Only discrete values of *Dst* are allowed. The user can select from among the possible Dst values by activating the up or down arrow buttons at the right side of the Dst display.

Eq Edge: The latitude of the equatorward edge of the diffuse aurora at midnight. Used only in *Standoff, Dst, Equatorward Edge* input mode. Only discrete values of equatorward edge are allowed. The user can select from among the possible values by activating the up or down arrow buttons at the right side of the Eq. Edge display.

Standoff: The magnetopause standoff distance is specified in Re. This input is used both by the *Vacuum Configuration* and *Standoff, Dst, Equatorward Edge* input modes. If the input mode is *Vacuum Configuration*, the user can enter arbitrary values for the standoff distance by editing the text box. Otherwise, if the input mode is *Standoff, Dst, Equatorward Edge*, only discrete input values are allowed. In this case, the user can select from among the possible *Standoff* values by activating the up or down arrow buttons at the right side of the *Standoff* display.

BFIELD-APP Outputs

Depending on the setting of the *Generate* button, the BFIELD application will produce (1) a 3D Gridded Data Set of the GSM coordinates and magnitude values of the B-Field, (2) a Field Line

Data Set containing field line traces from a constant MLAT, (3) a Field Line Data Set containing field line traces from a constant MLT, and (4) a Field Line Data Set containing field line traces representing a flux tube. The dipole tilt angle is also calculated and appears in the model status window.

The CRRESELE-APP Module

Model Name: CRRESELE
Version: July 1995
Developer: Air Force Research Laboratory
References: Brautigam, D.H., and J. Bell, CRRESELE Documentation, *PL-TR-95-2128*, Phillips Laboratory, Hanscom AFB, MA (1995), ADA 301770
Brautigam, D.H., M.S. Gussenhoven, and E.G. Mullen, Quasi-static Model of Outer Zone Electrons, *IEEE Trans. Nucl. Sci.*, **39**, 1797-1803 (1992)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESELE-APP Overview

The CRRESELE science and application modules are a UNIX port of the PC program CRRESELE developed and released by the Air Force Research Laboratory. More information on CRRESELE can be found in the CRRESELE Science Module section of this document.

The CRRESELE-APP module determines yearly electron omnidirectional fluences (differential and integral) for ten energy intervals in the range 0.5-6.60 MeV. A user-specified orbit is traced through the eight different CRRESELE outer zone electron flux models, at each energy, to provide an estimate of electron fluences received by the satellite under a wide range of magnetospheric conditions. The differential and integral omnidirectional fluences are calculated from the electron flux models as explained by this excerpt from the CRRESELE documentation:

“To obtain the desired yearly differential omnidirectional fluence and integral omnidirectional fluence, the time spent in each spatial bin traversed by the user-specified orbit is first determined. It is important to realize that only those spatial bins within the bounds of the model ($2.5 \leq L \leq 6.8$ and $1 \leq B/B_0 \leq 684.6$) are used in the fluence calculation. For a given spatial bin, the differential omnidirectional fluence [is calculated as the differential omnidirectional flux multiplied by the time spent in the bin] and the integral omnidirectional fluence for a given energy channel [is calculated from the product of the differential omnidirectional fluence and the appropriate energy bandwidths by summing over all energy channels with energy greater than the given channel]. [...] The final reported fluences are calculated by performing the summation over all traversed bins (within the model bounds) and then multiplying by [the number of days in 1 year divided by the duration of the orbit trace in days]. [...] The percent of time spent by the orbit outside the model bounds is provided in the [output]. It should be stressed again that the calculated fluences are from the outer zone electron belt only. A low Earth polar orbit will pass within the model bounds only about 15% of the time, whereas a nearly geosynchronous orbit will remain within the model bounds nearly 100% of the time.”

Note: The CRRESELE science module DOES NOT have to be run before running the CRRESELE-APP module.

CRRESELE-APP Inputs

The inputs to the CRRESELE-APP module are the orbit elements needed to calculate the satellite orbit. The Environment Window for the CRRESELE-APP module is the same as that for the SATEL-APP application. See the SATEL-APP Module section of the documentation for input descriptions.

CRRESELE-APP Outputs

The CRRESELE application generates a return text window which can be saved to a file. Included in the text are the orbit elements and tables of both the differential and integral omnidirectional fluences (in units of $\#/(cm^2 \text{ keV yr})$ and $\#/(cm^2 \text{ yr})$, respectively) calculated for all ten energy channels and all eight outer zone electron flux models. Also generated is a 1D Gridded Data Set giving the position of the satellite as a function of time.

The CRRESPRO-APP Module

Model Name: CRRESPRO
Version: 28 July 1994
Developer: Air Force Research Laboratory
References: Meffert, J.D., and M.S. Gussenhoven, CRRESPRO Documentation, *PL-TR-94-2218*, Phillips Laboratory, Hanscom AFB, MA (1994), ADA 284578
Gussenhoven, M.S., E.G. Mullen, M.D. Violet, C. Hein, J. Bass, and D. Madden, CRRES High Energy Proton Flux Maps, *IEEE Trans. Nucl. Sci.*, **40**, 1450-1457 (1993)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESPRO-APP Overview

The CRRESPRO application and science modules are a UNIX port of the PC program CRRESPRO developed and released by the Air Force Research Laboratory. More information on CRRESPRO can be found in the CRRESPRO Science Module section of this document.

The CRRESPRO-APP module calculates proton omnidirectional fluence (differential and integral) over the energy range 1-100 MeV for user specified orbits and quiet or active geophysical conditions. Fluences are calculated from the CRRES proton flux maps as explained by this excerpt from the CRRESPRO Documentation:

“To calculate differential omnidirectional fluences per year for an orbit input by the user, the time in seconds spent in each (L,B/B₀) bin is calculated [...] and the differential flux for each bin is multiplied by the time in seconds spent in that bin. The figures in the individual bins are then summed [and] the resulting figure is then multiplied by seconds per year divided by the sum of time in seconds for all bins [including the time the orbit spends outside the model region].”

Integral omnidirectional fluence for a given energy channel is calculated from the differential omnidirectional fluence by summing over all energy channels with energy greater than the given channel (eliminating those with overlapping energy ranges, channels 5 and 15) and multiplying by appropriate bandwidths, as discussed in the CRRESPRO documentation.

Note: The CRRESPRO science module DOES NOT have to be run before running the CRRESPRO-APP module.

CRRESPRO-APP Inputs

The inputs to the CRRESPRO-APP module are the orbit elements needed to calculate the satellite orbit. The Environment Window for the CRRESPRO-APP module is the same as that for the SATEL-APP application. See the SATEL-APP Module section of the documentation for input descriptions.

CRRESPRO-APP Outputs

The CRRESPRO application module generates a return text window which can be saved to a file. Included in the text are the orbit elements and tables of both the differential and integral omnidirectional fluences (in units of $\#/(cm^2 \text{ MeV yr})$ and $\#/(cm^2 \text{ yr})$, respectively) calculated for all 22 retained energy channels and for both active and quiet conditions. Also generated is a 1D Gridded Data Set giving the position of the satellite as a function of time.

The CRRESRAD-APP Module

Model Name: CRRESRAD
Version: 6 August 1992
Developer: Air Force Research Laboratory
References: Kearns, K.J., M.S. Gussenhoven, CRRESRAD Documentation, *PL-TR-92-2201*, Phillips Laboratory, Hanscom AFB, MA (1992), ADA 256673
Gussenhoven, M.S., E.G. Mullen, M. Sperry, K.J. Kerns, and J.B. Blake, The Effect of the March 1991 Storm on Accumulated Dose for Selected Satellite Orbits: CRRES Dose Models, *IEEE Trans. Nuc. Sci.*, **39**, 1765-1772 (1992)
Gussenhoven, M.S., E.G. Mullen, D.H. Brautigam, E. Holeman, C. Jordan, F. Hanser, and B. Dichter, Preliminary Comparison of Dose Measurements on CRRES to NASA Model Predictions, *IEEE Trans. Nucl. Sci.*, **38**, 1655-1662 (1991)

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

CRRESRAD-APP Overview

The CRRESRAD application and science modules are a UNIX port of the PC program CRRESRAD developed and released by the Air Force Research Laboratory. More information can be found in the CRRESRAD Science Module section of this document.

The CRRESRAD-APP module calculates expected satellite dose accumulation behind four different thicknesses of aluminum shielding for user specified orbits during quiet, active, or average geophysical activity levels. Dose accumulation is calculated from the CRRES dose rate maps for each of the four shielding domes (82.5, 232.5, 457.5, and 886.5 mils) and for each of the two dose rate detectors (HILET and LOLET) by determining the time in seconds that a specified orbit stays in a (L,B) coordinate bin and multiplying this time by the dose rate for this bin. These figures are then summed over the bins and multiplied by the number of seconds in a year divided by the sum of the time in seconds for all bins (including time the orbit spends outside the model region).

Note: The CRRESRAD science module need NOT be run before running CRRESRAD-APP.

CRRESRAD-APP Inputs

The inputs to the CRRESRAD-APP module are the orbit elements needed to calculate the satellite orbit. The widget set presented upon creation of a CRRESRAD-APP module is the same as that for the SATEL-APP module (see the SATEL-APP Module documentation section for details).

CRRESRAD-APP Outputs

The CRRESRAD-APP module generates a return text window which can be saved to a file. Included in the text are the orbit elements and tables of the accumulated yearly dose (in units of rads silicon/yr) for all four shielding domes and both detectors. Also generated is a 1D Gridded Data Set giving the position of the satellite as a function of time.

The IMAS-APP Module

Model Name:	The Ionosphere Analysis/Modeling System (IMAS)
Version:	November 1996
Developer:	Air Force Research Laboratory and Radex Inc.
References:	<p>Coleman, C.J., A General Purpose Ionosphere Ray Tracing Procedure, <i>Report SRL0131TR</i>, Defence Science and Technology Organization, Australia (1993)</p> <p>Daniell, R.E., Jr., L.D. Brown, D.N. Anderson, M.W. Fox, P.H. Doherty, D.T. Decker, J.J. Sojka, and R.W. Schunk, Parameterized Ionospheric Model: A Global Ionospheric Parameterization Based on First Principles Models, <i>Radio Sci.</i>, 30, 1499-1510 (1995)</p> <p>Jones, R.M., and J.J. Stephenson, A Versatile Three-Dimensional Ray Tracing Computer Program for Radio Waves in the Ionosphere, <i>OT Report 75-76</i>, US Govt. Printing Office, Washington, DC 20402 (1975)</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

Overview

Ionosphere Analysis/Modeling System (IMAS) consists of two main plotting windows and multiple child or "pop-up" windows to adjust the properties of the displays. On start-up, the IMAS software displays a global view in the plotting portion of the window below a full menu bar. When the user desires to venture into the ray tracing ability of the IMAS software, a second plotting window will be built. As with the main window, the drawing area of the ray tracing window is below a menu bar. The appearance of the graphics area depends on the status of the PIM data; it either contains a 2D axis or is blank. Consult the following sections to determine how to best use IMAS to fulfill the user's graphic needs.

Main Window

IMAS's many accessories are contained under the menu bar selections located above the plotting area. Choices contained in the menu bar include: *File*, *Rendering*, *Animate*, *Viewer*, and *Utilities*. In the drawing area, the Earth is shown at lat=0.0 lon=0.0 with the continents in outlined format. To the right is a color bar with the title *No Data* to alert the user that no data is available to plot. The *Exit* command is contained under the *File* menu choice which will remove the IMAS display from the user's window system and clear out any data loaded or processed from memory.

Select *Open* under the *File* menu to load in the desired PIM data file. A standard Motif file selection popup will appear containing a scrolling list, a message requesting a PIM data file, a text field showing the current working directory and a series of buttons. The scrolling list displays the contents of the directory specified by what is shown in the Selection window below. The user can either double click on the desired file or directory in the scrolling list or highlight the file by single clicking on it and then pressing the *OK* button. When a valid PIM data file is selected, the message area will show the percentage read in from the file. After the entire data file has been processed by the software, the file selection popup will be removed from the display.

Under the *Rendering* menu are choices that affect how the Earth and any active data is presented in the main plotting window. This menu is a tear-off menu; when the dashed lines at the top of the menu are selected, the menu will become a “popup” style window. *Outlined* and *Filled* control how the continents are drawn on the 3D Earth plot. The IMAS software starts up in outlined form, but the user can change it at any time. The outline mode is good for close to real-time movement when adjusting the viewer’s position, while filled mode stands out better for static presentations but takes longer to render.

A series of checkboxes are also contained under the *Rendering* menu choice. The first, *Political Bounds* will show all current political boundaries on the continents. *Ionosphere* will show the current ionosphere slice being used for ray tracing. To see any active ray traces, select *Visible Rays*. When the *Ground Points* selection is active, the points where the currently active rays hit the Earth’s surface are shown as green half spheres. The only exception to this is the transmitter whose location is distinguished by coloring it dark purple.

Animation is possible through the *Animation* menu, whose options include *Orbit*, *Density*, and *Stop*. To rotate the globe on its axis, choose *Orbit*. *Density* increments through the altitudes in the PIM density matrix and therefore only works if PIM data is loaded. If the user wants to halt animation for a moment, but allow it to later continue from where it was paused, choose *Stop*. Canceling any active animation option is done by clicking on the appropriate check box in the *Animation* menu. This menu has the same tear-off ability as the *Rendering* menu described above.

There are three methods for adjusting the user’s view of the Earth and any active plots. The *Viewer* menu contains a choice *Location* which will show a popup with two sliders, one for latitude and one for longitude. Position of view can be adjusted by either dragging with the slider box or clicking on the slider line to increment by degrees of 1. Also contained under the *Viewer* menu is the *Zoom* choice. This brings the viewer closer or further away from the Earth. The *Move* selection brings up a window containing two sliders, which change the position of the Earth within the window. Below these sliders is a label telling the user which axes will be effected, either the X or Y. Finally, a checkbox labeled HUD (Heads-Up-Display) closes out the contents of the *Viewer* menu. When activated, information related to the data loaded will be displayed over the Earth plot making it easy for the user to view any changing values.

All functions contained under the *Viewer* menu can be controlled with the mouse. The left mouse button corresponds to the *Location* choice by rotating the Earth based on how the pointer is dragged. To change the *Zoom* value, hold down the middle mouse button and drag the pointer up to zoom away and drag down to bring the Earth closer. Pressing the third mouse button and dragging will change the position of the Earth, the same as the sliders under the *Move* popup. If your mouse only has 1 or 2 buttons, please use the popups under the *Viewer* menu to change the values corresponding to the functionality of the missing mouse button(s).

PIM

Displaying information from the Parameterized Ionosphere Model (PIM) is one of IMAS’s main functions. PIM data is brought into the software by selecting *Open* under the *File* menu. This will bring up the file selection popup whose usage is outlined above. To generate a PIM data file the PIM Science Module can be used.

To see the list of viewing options, choose *Global* under the *Plots* submenu from PIM. On the left are a list of different layers available to plot from the PIM output, such as *foF2*, *hmF2*, and *Den-*

sity. A slide bar labeled *Density at Altitude* has been provided to view different layers of the density matrix. This will increment through the altitude matrix corresponding to the current PIM run with the value of the altitude shown above the slider.

When the *Min/Max* button at the bottom of the PIM Options window is pressed, a popup appears with two text fields and a series of buttons. The text fields allow the user to edit the minimum and maximum data values for the currently active PIM data. When the *Apply* button is pressed, the values contained in the fields are accepted and the 3D plot area will show the effects of the change. The *Load Orig* button will show the original min/max values for the selected PIM data set and *Load Prev* will load in the last min/max values the user applied. To remove the popup from the user's display, press the *Dismiss* button.

Options for the other PIM data values also exist. To plot the values of foF2 or foE with the altitude from the hmF2 or hmE matrix, click on the check box labeled *Plot fo @ hm*. To help better show the peaks formed by this plotting selection, a slider entitled *Altitude Scale* is provided. This will exaggerate the altitude of the ionosphere layer around the Earth and will work with any of the global plot selections.

By activating the *Show Day/Night* checkbox, the day night terminator can be displayed on the 3D globe using the time and day values passed into the program from the PIM data. The terminator is shown as a contrast between light and shade from a simulated light source. When this option is active, the only object affected by the light is the globe; the colors of any data plots are not altered.

To allow any data plotted over the Earth to be transparent, the slider labeled *Transparent Value* should be used. The lower the number, the less the intensity of the colors representing the PIM data. This transparency value only affects global PIM data plots. Ray trace and ionosphere data are not effected.

Ray Tracing

Ray tracing allows the user to plot the behavior of a ray in the ionosphere specified by the currently loaded PIM data. Entering the transmitter coordinates and the desired frequency and elevation of the ray will cause the software to show the resulting ray using the Australian 2D ray tracing algorithm [Coleman, 1993]. To show the ray tracing main window, choose *Ray-Trace* from the *Utilities* submenu of the IMAS Window. If a PIM data file is currently loaded, the window will come up with an axis (Generate data files using the PIM Science Module).

First, choose *Transmitter...* under the *Ray-Trace* menu to bring up the window to specify the source coordinates for the ray. The user may enter the latitude and longitude for the desired transmitter and press *Apply* to tell the program to use the entered values. For frequently used coordinates, the user can assign a label and save the values in the transmitter list by pressing the *Save* button when all fields are completed. This way the next time all the user has to do is select the transmitter from the list on the right of the popup and either press the *Apply* button or simply double-click on the desired location. If a bad value was saved, the user can change the data contained in the list by selecting the appropriate transmitter label, changing the values and pressing the *Update* button. Keep in mind that neither the *Save* nor the *Update* button tell the software to change the current data values for the transmitter location, you must either press *Apply* or double-click on the desired location. To dismiss this popup without affecting the currently set transmitter location, press the *Cancel* button. When a location is selected and applied, the transmitter location popup will disappear.

The *Australian 2D Model* ray tracing algorithm provides the ability to plot rays along an arbitrary azimuth, select the range limit and set the maximum number of hops the ray can take. These options can be changed by bringing up the 2D ray trace options window. First, choose *Freq-Elev* under the *Ray-Trace* menu and at the top of the window, the *Australian 2D Model* option will be selected and next to it is a button labeled *Ray Trace Options*. Activating this button will bring up a window containing three slide bars, each with a text field above them and a label below indicating the currently set value for each option. After either the azimuth or range values are changed, the software builds a new ionosphere slice and deletes all previously built rays. To remove the popup from the user's display, press the *Dismiss* button.

To build a ray trace, the user must next select the desired frequency and elevation by choosing *Freq/Elev* under the *Ray-Trace* menu. The user is presented with a display containing two identical slider/text box areas, the only difference being the labels *Freq.* and *Elev.* The user can manipulate the slide bar below the label to adjust the desired field or enter a specific value by clicking the mouse over the desired field and manually typing in the value. If the value entered is greater than the maximum the slider is set at, the slide bar will use the entered value as its new maximum. When the *Single* toggle button is active, the value in the first text box will change along with the activity on the slider and only one ray will result from the run. If a range of data values is desired, click on the *Multi* box or click the mouse when the pointer is in the text field following the *to* label. As a result, any movement on the slider will result in the data value in the *to* field being updated. To stay in *Multi* mode and change the value in the *From* field, press the first mouse button inside the *From* text field and adjust the value as desired. When multiple rays at a certain incremental value are needed, the user can change the *Step* value by using the up and down arrows. For example, if the display showed 5.0 in the first field and 20.0 in the second with a step value of 5, rays would be built for values of 5.0, 10.0, 15.0 and 20.0. When multiple frequency and elevation values are requested at the same instance, the return time for the data can be slow, please plan accordingly.

Once the values in the frequency and elevation fields are entered, press the *Plot Ray* button. If this is the first time since start-up a ray has been built or the transmitter location has been changed, a message will appear alerting the user that a new ionosphere is being built. Otherwise, a message will be shown telling the user the frequency and elevation of the ray being built.

When multiple rays are being displayed and the user would like to know the frequency and elevation of a specific ray, press the *Plot List* button. In this popup, two scrolling lists are displayed, one showing the frequency and elevation values of the rays currently built and the other shows which are currently plotted. When the user selects a line from the *Displayed* list, the ray corresponding to the selected entry will be plotted as white. If the same ray is selected again, the ray is not plotted and an "(H)" will appear in front of the frequency and elevation entry in the scrolling list to alert the user that it is hidden from view. To reactivate the hidden ray in the plot, select the line again. To remove the popup, press the *Dismiss* button at the bottom of the window.

Within the main ray trace plotting window, the user can press the left mouse button and drag to an area the user would like to see enhanced. To see the selected area, choose *Magnify...* under the *View* menu. The resulting window will contain the area selected by the user to view. Under the *Options* menu, the user can change how the selected area appears and how big the area is. Choose *Scale* to change the size of the grab area and choose *Zoom* to enlarge or reduce the pixel size. *Exit* will remove the popup from the user's display.

If the user wishes to change the maximum altitude value for the y axis in the main plotting area, choose *Set Alt* under the *View* menu. Adjusting the slider will change the maximum altitude value. In addition, the user may press the middle mouse button and drag the pointer up to reduce the maximum value and down to increase it.

Because the 2D model is being used, the *Overhead* choice from the *View* menu only plots a straight line because no drift is present in the model. However, the *Den vs. Alt* choice will show a plot of density vs. altitude for the current ionosphere. The latitude, longitude, and range of the current plot is displayed in text fields below a slide bar. To plot different areas of the slice, move the slide bar and the data for the appropriate latitude, longitude, and range will be shown. In addition to the ionosphere data, the foF and FoE values are also plotted using the hmF2 and hmE values for the altitude. A check box to the left of the slider allows the user to activate a grid on the plot area to aid in determining specific values on the curve.

Jones-Stephenson 3D Homing Model

A new version of the Jones-Stephenson 3D ray trace model [Jones and Stephenson, 1975] has been acquired by developers at AFRL. Contained in this new version is the capability to perform homing between two given points with a user supplied frequency value. The current release of the homing model only allows for ground-to-satellite calculations and the IMAS interface has been designed for that purpose.

To start the homing interface, select *Homing* from the *Utilities* menu in the IMAS main window. The homing input window ("homingInputBB_popup") will appear. If a default start-up file or a user's defaults file is available then the window should start-up with the appropriate saved values. Otherwise all text fields will be blank.

The window is separated into 6 distinct tool groups: *TRANSMITTER*, *RECEIVER*, *Parameters*, *OUTPUT*, *Plot Options*, and *Controls*.

TRANSMITTER

This portion of the interface controls the user's choice of coordinates for a ground based transmitter. It contains two text fields that allow the user to change the latitude and longitude of the transmitter. The altitude field is currently fixed equal to zero. With these text fields the user may manually enter any point on the Earth's surface desired.

The two scrolling lists next to the text input area, *Countries* and *Cities*, allow a short-cut method of entering a number of common coordinates. When a country is selected, all cities the database has available are placed in the *Cities* list. The user can select from the *Cities* list and the appropriate coordinates for the selected city will be entered into the text fields. If the user types the first letter of a label when the mouse pointer is within either scrolling list area, the list will show the first country or city beginning with the entered letter.

If the user enters a value into the *Lat* or *Lon* text fields and presses the Tab key, the entered coordinate is shown as a light green cone beginning at the point specified and extending upward in the IMAS 3D display area. The same result occurs when a value in the *Cities* list is selected.

The label text field automatically contains the value of the user selection from the cities list. This text field can be edited by the user without effecting the homing transmitter coordinates.

When the desired latitude and longitude values are entered, press the *Apply* button. In the 3D display, the cone will be replaced by a light green half-sphere. This will allow the user to know where the last applied transmitter coordinates were if the values are changed. In addition, the text field labeled *Value* at the top of the *TRANSMITTER* control group will show the applied transmitter label and coordinate set.

Due to the size of the homing control window, a *Hide* button has been provided. Pressing *Hide* will hide everything within the control group except the *Value* field and the *Edit* button. Click on the *Edit* button to redisplay the control group.

RECEIVER

Most of the controls in the *RECEIVER* control group have the same functionality as in the *TRANSMITTER* group. The only differences are that the altitude text label is activated and only one scrolling list is displayed with text fields to enter date values. The scrolling list contains the names of all satellite elements available. By selecting a satellite label and entering a date and time, the appropriate coordinate set is loaded into the text fields, the satellite's position is calculated, and a red cone is shown on the 3D display. The point of the cone represents the coordinates of the satellite. Sometimes the satellite coordinates will be outside the user's currently displayed 3D area and some rotating and zooming may be needed. When the user clicks on the *Apply* button the cone is replaced with a red sphere.

The "fast search" feature described above for the *Countries* and *Cities* scrolling lists is also available for the satellite list.

Parameters

The only additional input value for homing is the desired frequency emitting from the transmitter in megahertz. Use the text field labeled "Freq" to enter this value. Next to the text field is a set of arrows. To increment the frequency value by one, click on the up button and click on the down arrow to reduce the number by one. If the user presses and holds the mouse button over either one of these fields, the value will increment or decrement until the button is released.

OUTPUT

The text fields in this group, "Elev" and "AZ", will contain the elevation angle and azimuth value as a result of a successful homing run.

Plot Options

Once the user successfully runs homing and has an active plot in the 3D display, an ionosphere slice can be plotted along the resulting azimuth path using the currently loaded PIM data by checking the *Plot Ionosphere Slice* control. Checking the *Show Text Labels* control will allow the user to see the labels associated with the coordinates on the 3D display.

Controls

After a desired set of transmitter and receiver coordinates has been entered along with a frequency value, the user can press the *Run homing* button to submit these values to the homing model. When complete, the resulting ray will appear on the 3D display and the elevation and azimuth values will be shown in the *OUTPUT* text fields.

Save Defaults saves the currently selected values to a defaults file. The next time the user opens the homing interface, these saved values will be restored.

After multiple homing plots have been built, the user can view a list of previously built points by pressing the *Plot List* button. A window will appear listing all successful homing runs by transmitter and receiver label and frequency. The user can plot the result of any run in the *homing Points* list by selecting the appropriate label. After being selected, the label is added to the *View Data For:* list. By selecting a label from the *View Data For:* list, the homing input window will load in the values the user requested to create the output. Any number of homing Points can be displayed at one time, but data can only be viewed for one ray at a time. Press the *Dismiss* button to remove this popup from your display.

The *Dismiss* button removes the homing control window from the user's display.

The LET-APP Module

Model Name:	CRRES/SPACERAD Heavy Ion Model of the Environment (CHIME) and CRRESPRO
Version:	3.5 (December 1995)
Developer:	Lockheed Martin Advanced Technology Center and AFRL, adapted to AF-GEOSpace by Radex Inc.
References:	<p>Chenette, D.L., J.D. Tobin, S.P. Geller, CRRES/SPACERAD Heavy Ion Model of the environment, CHIME, <i>PL-TR-95-2152</i>, Phillips Laboratory, Hanscom AFB, MA (1995) (User's guide for Version 3.5), ADA 321996</p> <p>Chenette, D.L., J. Chen, E. Clayton, T.G. Guzik, J.P. Wefel, M. Garcia-Munoz, C. Lopate, K.R. Pyle, K.P. Ray, E.G. Mullen, D.A. Hardy, The CRRES/SPACERAD Heavy Ion Model of the Environment (CHIME) for Cosmic Ray and Solar Particle Effects on Electronic and Biological Systems in Space, <i>IEEE Trans. Nucl. Sci.</i>, 41, 2332-2339 (1994)</p> <p>Feynman, J., G. Spitalé, J. Wang, and S. Gabriel, Interplanetary Proton Fluence Model: JPL 1991, <i>J. Geophys. Res.</i>, 98, 13281 (1993)</p> <p>Meffert, J.D., and M.S. Gussenhoven, CRRESPRO Documentation, <i>PL-TR-94-2218</i>, Phillips Laboratory, Hanscom AFB, MA (1994), ADA 284578</p>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

LET-APP Overview

The Linear Energy Transfer (LET) Application Module and CRRES Heavy Ion Model of the near-Earth Space Environment (CHIME) Science Module are a UNIX port of the PC program CHIME (with modifications) developed and released under the auspices of the Air Force Research Laboratory. More information on CHIME can be found in the CHIME Science Module section of this document.

The LET-APP Module calculates the LET spectra and associated Single-particle Event Upset (SEU) rate in an electronic device for a user-specified location or orbit. In addition to the Galactic Cosmic Rays (GCR), Anomalous Component (AC), and Solar Energetic Particles (SEP) modeled in the original CHIME, AF-GEOSpace provides the capability to include trapped protons, as specified by the CRRESPRO model (see the CRRESPRO Science Module section of this document), in the calculation of LET spectra and SEU rates. The importance of the LET spectra and method of determination are described as follows in the CHIME User's Manual:

“For the purposes of estimating single-particle upset effects (including latchup), the heavy ion flux distributions as a function of particle type and energy are transformed into distributions as a function of the ion's linear energy transfer (LET). The LET is the energy lost by an ion and deposited into the target material per unit distance along the ion's path. LET generally increases with the atomic number of the ion (Z) and generally decreases with increasing velocity (V) approximately as Z^2V^{-2} (except at low and high velocities where

atomic effects and relativistic effects, respectively, become important). Thus a faster iron ion and a slower oxygen ion can have the same LET and, by assumption, the same ability to produce a single event upset in a specific device. The LET spectrum is a convenient way to integrate and keep track of the contributions of the various ion species and energies, ordered according to LET.”

“The LET spectrum calculator in CHIME employs an integral method and a two-part (shield and target) spherical geometry model. The thicknesses of the shield and the target are specified by the user in one of several column density units: milligrams per square centimeters (mg cm^{-2}), mils of aluminum equivalent, or microns of silicon. Since the range of an ion depends on the density of the target and only weakly on the target composition, the mass density option (mg cm^{-2}) permits the model to be used with different materials, e.g., GaAs.

Working from the sensitive region out, and for each ion species, minimum and maximum incident ion energies are calculated corresponding to pre-defined LET thresholds. At each threshold LET, the integral LET spectrum is calculated by integrating the heavy ion flux spectrum over this energy range and summing over all particle species. The method and its results have been described in greater detail by *Chennette et al.* (1994).”

The LET spectrum is calculated both for the interplanetary flux environment model and for the near-Earth flux distribution, shielded by the effects of the Earth and its magnetic field. For the GCR, AC, and SEP, the interplanetary LET spectra will always be a ‘worst case’ in terms of energy deposition. If the trapped proton option is selected, both the interplanetary and shielded LET spectra are modified to include the trapped proton fluxes corresponding to the user-specified orbit or location. To compute the geomagnetically shielded fluxes used in the LET calculation, a geomagnetic filter function is computed (see CHIME Science Module) for either the user-specified location or as an average over a user-specified orbit. This filter function is then applied to the GCR, AC, and SEP particle spectra used in the LET spectra computation. For the trapped protons, the LET spectrum is calculated separately at each point along an orbit and then averaged before being added to the total LET spectra (the limiting case is a single point if a location is specified).

The method for determining SEU rates is described in the CHIME User’s Manual as follows:

“To calculate a single-particle upset rate, CHIME combines the LET spectrum, calculated as described above, together with user specifications or measurements of the upset cross section, and a model for the geometry for a specific device, and performs a numerical integration. This procedure incorporates a rectangular parallelepiped model like that of Pickel and Blandford [*IEEE Trans. Nuc. Sci.*, **NS-27**, 1006, 1980] to estimate the geomagnetic factor of the sensitive region as a function of path length. It provides a way to allow the user to input a measured upset cross-section (as a function of LET) as an improvement on the ‘step function’ approximation. The only restriction on this tabulation is that it must be monotonic non-decreasing with increasing LET. This method and its sensitivity to assumptions of the geometry model have been described by Shoga et al. [*IEEE Trans. Nuc. Sci.*, **NS-34**, 1256, 1987]. It is a direct application of a few simple geometrical concepts.”

“The upset rate is determined as the rate at which energetic heavy ions in the space radiation environment can deposit more than a certain minimum amount of energy into a spe-

cific volume. The minimum energy deposit required to cause an upset is called the upset threshold. The specific volume is the sensitive volume of a cell in the device. The single-particle upset rate is determined from the product of the local particle flux or fluence and the geometrical factor presented by the sensitive volume.”

In LET-APP the parameters of the on-board microelectronic device can be specified in the window or read from a device file. The user is urged to consult the CHIME User’s Manual for more details of the SEU rate calculation and required formats for the device input files.

Note: The CHIME Science Module need NOT be run before using the LET-APP module.

LET-APP Inputs

Input to the LET-APP application comprises the inputs required to run the CHIME model, as adapted from the PC version. Several methods for inputting variables are available. The input window is logically divided into three areas: an environment specification section, a satellite location and/or microelectronic device section, and an auxiliary section for controlling module output.

Specify Environment:

Flux Input:	Several methods for generating cosmic ray fluxes (Galactic Cosmic Rays/ Anomalous Component Spectra) are provided. The options are:
Off:	No cosmic ray fluxes generated.
Modulation:	CHIME provides fluxes corresponding to the “Level” (entered in the text box, approximate range: 400 to 1600 megavolts) of solar modulation selected from a full range of monthly values over the period 1970-2010.
Period:	CHIME computes the average of the fluxes for each ion species over the user-specified time interval entered in the “Year 1”, “day 1”, “Year 2”, and “day 2” text boxes activated when this option is selected. Tabulated monthly values of the solar modulation parameter for the period 1970-2010 are used.
Solar Events:	The CHIME model provides several models for specifying the flux or fluence of heavy ions originating at the Sun as a result of solar energetic particle (SEP) events. The options are:
Off:	No SEP event related flux/fluence is generated.
March 91 Peak:	Model based on peak CRRES measurements from the March 1991 event
June 91 Peak:	Model based on peak CRRES measurements from the June 1991 event
March 91 Ave:	Model based on average CRRES measurements from the March 1991 event
June 91 Ave:	Model based on average CRRES measurements from the June 1991 event

JPL 1991 Model: Models based on statistical distributions of solar proton event intensities (JPL 1991, *Feynmann et al.*, [1993]). It provides the proton fluence which would be exceeded at a probability level of occurrence (*Pr*), or confidence level, from 50% to 0.1%. If the *Flux Inputs* option *Off* or *Period* is selected above, then fluxes are calculated from the fluences using the user-specified time interval. If *Modulation* is selected as the *Flux Inputs* option, then a random period of 1 year is used.

Note: The cosmic ray flux input and solar event options are identical to those used in the CHIME Science Module.

Atomic Z: Two ranges for the ion species atomic number can be specified, the full range (*1 to 92*) or a reduced range (*1 to 30*) which may be used to save calculation time. If the full range is specified, the code uses tabulated values for hydrogen (*Z=1*) to nickel (*Z=28*) and all ions heavier than nickel are modeled using abundance ratios to iron.

Trapped protons: Two models of trapped protons in the radiation belts corresponding to a quiet and active period, *CRRESPRO Quiet* and *Active*, are available (see *CRRESPRO* Documentation). The *CRRESPRO* flux data is read in for all available energies and incorporated into the CHIME system, using the same LET and SEU algorithms as for the cosmic ray protons.

Specify Satellite/Device:

Sat. Location: Input the satellite location as a single point or specify an entire orbit:

Single Point: The pop-up menu for the point asks for the satellite's radius(km), latitude(degrees), and longitude(degrees).

Orbit: The pop-up menu for the orbit requires a set of orbit elements. The orbit elements can be of two types:

Mean elements: These are the same as the elements that are normally read in by the *SATEL-APP* module, except there are no derivative or drag terms.

Chime elements: These simple elements represent the original inputs to the CHIME propagator and consist of the above *Mean elements*, except that the mean anomaly is fixed at zero, so the reference time becomes the time of perigee, and the eccentricity and mean motion are replaced by altitudes for apogee and perigee.

Entering a set of *Mean elements* and then selecting the *Chime elements* toggle effects a translation to Chime

elements. The *DFLTS* button sets all orbit elements to default values taken from the PC report.

Note: The CHIME simple elements are listed as those parameters differing from the mean elements (right column) and those in common with the mean elements (left, highlighted). If entering *Mean elements*, one must convert to CHIME elements (by then selecting the *Chime elements* toggle) before running because the CHIME propagator only uses the CHIME simple elements.

From File: The *From File* button enables one to read in an input file containing mean orbital elements, in analogy to the SATEL-APP module. The mean elements are automatically converted to the equivalent simple elements for use by the CHIME propagator. The *Update* button ensures that the start, stop times and intervals are up to date. The *Orbit* popup window is automatically updated to show the parameters that were read.

SEU Device: The on-board microelectronic device can be specified by individual parameters or from a device file:

Parameters: The pop-up menu sets the device parameters as required for a single energy deposit SEU calculation. They include the *LET threshold*, the *Upset Cross-Section*, the number of *Bits per device*, the *sensitive region* dimensions (*X*, *Y* are transverse, *Z* is depth) and the *Density of material*.

From File: The pop-up presents a file selection menu. The currently listed files are those that came with the PC distribution. They contain detailed upset cross-sections versus LET, for input into the calculation of integrated SEU rates.

Thickness: The pop-up menu sets the *Shield* and *Target* thicknesses. The units for each can be toggled between three choices: *mg/cm²*, *mils Al*, and *microns Si*.

Let Set: The pop-up menu sets the minimum (*LETMIN*), maximum (*LETMAX*), and number of points (*NLETS*) for the LET spectrum.

LET-APP Outputs

The LET application outputs a summary text file for the selected case. The text file may be accessed by three toggle options:

SEU: Shows the final SEU rate for the case. The results are presented in two forms: a “worst case” which has the geometrically unshielded cosmic ray and/or solar flare rate (*wo_Bgeo*) along with any trapped proton contributions and a “best case” which is the same except that geometrically shielded cosmic/solar particles (*w_Bgeo*) are used. If the trapped protons are not included, then the rates should be the same as for the original PC version (there called interplanetary and geomagnetically shielded rates).

LET: This describes the two LET spectra that are used as input to the SEU rate calculation. The two flux columns represent the “worst/best” case results.

LET/TRAPPED: This contains the original PC version cosmic ray and/or solar flare LET geometrically unshielded and shielded components, and in a separate column, the trapped proton LET contribution.

Options *SEU* and *LET* above are, with some minor changes, the same as the output printed by the PC version of CHIME in the .SEU and .LET files.

Hit the *Display Text* button to update and display the current text window.

LET-APP outputs a 1D plot of the LET spectrum (see above) in the form of a log-log function, for the selected case. The LET spectrum represents the total flux of particles of all types with an energy deposit per thickness (MeV/mg/cm^2) larger than the threshold for the bin. The two data lines represent the “worst/best” case LET results, as described above. Note that if the JPL solar flare model is chosen, flux is replaced by fluence. Hit the *Display Plot* button to display the 1D plot.

The *Plot Options* button pops up a menu used for modifying the X and Y axes of the 1D plot.

The LET application also outputs a 1D Gridded Data Set of the position of the satellite as a function of time. The orbits can be single points or a complete trajectory, as calculated by the CHIME propagator.

The SATEL-APP Module

Model Name: LOKANGL and SPACETRK (SGP4)

Version: LOKANGL: 18 August 1997
SPACETRK (SGP4): 15 August 1997

Developer: LOKANGL: Radex Inc.
SPACETRK (SGP4): Air Force Institute of Technology (modified by Radex, Inc.)

References: Bass, J.N., K.H. Bhavnani, B-Z.J. Guz, R.R. Hayes, P.N. Houle, S.T. Lai, and L.A. Whelan, Analysis and Programming for Research in Physics of the Upper Atmosphere, *AFGL-TR-76-0231*, p. 56-71 (1976) (LOKANGL), ADA 034066

Kerns, K.J., and M.S. Gussenhoven, CRRESRAD Documentation, *PL-TR-92-2201*, Phillips Laboratory, Hanscom AFB, MA (1992) (LOKANGL), ADA 256673

Hoots, F. R, and R.L. Roehrich, SPACETRACK Report No 3, available at the web site <http://celestrak.com/NORAD/documentation/index.html>

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

SATEL Overview

The SATEL application module provides an interface to the LOKANGL and SGP4 orbit generation and prediction codes. The interface and code generation are shared among several modules requiring code orbit ephemerides. Other modules using the orbit generation module are the CRRESRAD, CRRESPRO, and CRRESELE applications.

SATEL Inputs

Input to the SATEL application comprises orbital elements, start and stop times of the orbit interval to be predicted, and parameters defining detector and link options. Several methods for inputting the orbital elements are available.

The input window is logically divided into three areas: a propagator/element type section, an orbital element input section, and an auxiliary input area. The paragraphs below will describe the inputs requested by each of the three logical input areas.

Propagator/Element Type Specification

The SATEL application allows the orbit to be generated by using either the LOKANGLE or SGP4 orbit propagator codes. In addition, the orbital elements to be used by the propagator may be specified in a variety of ways.

The *Propagator* input section allows the user to specify which of the following propagators to use in calculating the orbit,

Lokangle: Lokangle, an orbit prediction code developed by Radex, Inc. (see notes below).

SGP4: The SGP4 portion of the SPACETRK code developed by the Air Force Institute of Technology.

The *Element Type* input section allows the user to specify how the orbital elements will be input. The choices are

Mean Elements: The Mean orbital elements will be specified. When this selection is chosen, the orbital element input section will display text boxes and labels for input of Inclination, Arg. of Perigee, Mean Anomaly, Eccentricity, Right Ascension of Ascending Node and Mean Motion of the satellite. See *Mean Elements Inputs* below for more information.

P/V (ECI): The Position/Velocity orbital elements will be specified. When this selection is chosen, the orbital element input section will display text boxes and labels for input of three position components and three velocity components. See *P/V (ECI) Inputs* below for more information.

Solar: The Solar orbital elements will be specified. When this selection is chosen, the orbital element input section will display text boxes and labels for input of Inclination, Apogee, Perigee, and local time of Apogee and maximum latitude. See *Solar Inputs* below for more information. If the Perigee altitude is less than the Apogee value entered then an error popup window appears and a message is written to standard output.

SMean: The Simple Mean orbital elements will be specified. When this selection is chosen, the orbital elements input section will display text boxes and labels for input of Inclination, Right Ascension of Ascending Node, Argument of Perigee, Apogee Altitude, and Perigee Altitude (Mean Anomaly is fixed equal to zero). See *SMean Inputs* below for more information. If the Perigee altitude is less than the Apogee value entered then an error popup window appears and a message is written to standard output.

From File: It is common to store orbital elements in files of two-line NORAD orbital elements. The *From File* option allows a user to choose a file containing a series of two-line NORAD elements. When this option is chosen, the orbital element input section will display a list of satellite names corresponding to the element sets read from the specified file. See *Select From File* below for more information on this choice, the format of the NORAD element set file, and how to obtain a file of orbital elements via FTP.

Several points should be kept in mind when choosing a propagator and input method:

(a) Lokangle allows multiple element sets (each at a different reference time) to be used for a single satellite. This allows Lokangle to interpolate smoothly between the element sets, thus avoiding the discontinuities which appear when errors accumulate in the propagator. Currently, multiple element sets can only be entered by using the *From File* input method. SGP4 does not support multiple element sets. Running SGP4 with multiple element sets will cause an error.

(b) Lokangle supports all of the provided *Element Type* options. SGP4 supports all *Element Type* options except the position-velocity element option, namely *P/V (ECI)*. Attempting to run SGP4 with the *P/V (ECI)* option will cause an error.

Element Input Section

The user sees one of five sets of text fields depending on which orbital *Element Type* has been selected,

(1) Mean Elements Inputs,

Inclination:	The inclination of the satellite orbit specified in degrees.
Arg. of Perigee:	The argument of the perigee of the satellite orbit measured in degrees.
Mean anomaly:	The mean anomaly of the satellite orbit specified in degrees.
Eccentricity:	The eccentricity of the satellite orbit.
R. A. Asc. Node:	The right ascension of the ascending node of the satellite orbit specified in degrees.
Mean Motion:	The mean motion of the satellite, specified in rev/day.
d(MM)/dt/2:	One-half the first time-derivative of the mean motion of the satellite. Specified in rev/day ² .
d2(MM)/dt2/6:	One-sixth the second time-derivative of the mean motion of the satellite. Specified in rev/day ³ .

Note: The PC-based versions of the CRRESELE, CRRESRAD and CRRESPRO applications do not use the mean motion time derivatives in the orbit calculations. Although the differences should be small, if precisely matching the PC-based results is important to the user, d(MM)/dt and d2(MM)/dt2 should be set to zero when running the CRRESELE, CRRESRAD and CRRESPRO applications.

(2) P/V (ECI) Inputs,

Px, Py, Pz:	The X, Y, and Z position of the satellite, specified in km. The coordinate system is Earth Centered Inertial (X = first point of Ares, Y = X x Z, Z = north rotational pole).
Vx, Vy, Vz:	The Vx, Vy, and Vz velocity components of the satellite, specified in km/s. The coordinate system is Earth Centered Inertial (X = first point of Ares, Y = X x Z, Z = north rotational pole).
P. Decay:	The period decay of the satellite orbit, specified in s/rev.

Note: The PC-based versions of the CRRESELE, CRRESRAD and CRRESPRO applications do not use the period decay in the orbit calculations. Although the differences should be small, if precisely matching the PC-based results is important then *P. Decay* should be set to zero when running the CRRESELE, CRRESRAD and CRRESPRO applications.

(3) Solar Inputs,

Inclination:	The inclination of the satellite orbit specified in degrees.
Apogee (km):	The altitude of the satellite orbit apogee specified in kilometers.
LT of Max Lat:	The local time of maximum latitude (inclination) specified in hours.

Perigee (km): The altitude of the satellite orbit perigee specified in kilometers.

LT of Apogee: The local time of apogee specified in hours.

(4) SMean Inputs,

Inclination (deg): The inclination of the satellite orbit specified in degrees.

RAA Node (deg): The right ascension of the ascending node of the orbit specified in degrees.

Perigee Arg (deg): The argument of the perigee of the satellite orbit measured in degrees.

Apogee Alt (km): The altitude of the satellite orbit apogee specified in kilometers.

Perigee Alt (km): The altitude of the satellite orbit perigee specified in kilometers.

(5) Select From File,

Files containing sets of NORAD two-line element sets are commonly available. The *From File* input option provides a means of reading files containing element sets and using them to generate orbits in AF-GEOSpace. When the *From File* button is activated the Ephemeris Data window displays a label showing the currently opened file, a *Select File* button to open a file selection box to change the current file, and a list of elements parsed from the current file. When the *Sort* button (next to the *Select File* button) is checked, the next execution of *Select File* returns an alphabetically sorted list of elements parsed

After a file is opened the user can click the desired label in the element selection box to choose the orbit elements associated with the named satellite. When this is done, a pop-up box will appear showing the chosen elements. If more than one element set was chosen for a single satellite, the scrollbar at the bottom of the box can be used to view the chosen element sets.

In order to correctly parse the element sets, AF-GEOSpace expects the chosen file to contain elements in a specific format. Information on the supported NORAD two-line element format is available from Celestrak.com via anonymous ftp (see below). A copy of this document may also be found in \$PLGS_MODELS/MODELS/data/EPHEMERIS/tle.doc.

Standard installation of AF-GEOSpace Version 1.4 sets the default start-up element file as, \$PLGS_MODELS/MODELS/data/EPHEMERIS/tle.new

Files containing ephemeris data for a large number of current and historic satellites are available from Celestrak.com. Current element files from the last 30 day's launches, for example, can be downloaded via anonymous ftp and used as the default start-up element file as follows,

```
cd $PLGS_MODELS/MODELS/data/EPHEMERIS
ftp ftp.celestrak.com (log in using the username anonymous)
ftp> cd /pub/elements
ftp> get tle-new.txt
ftp> quit
mv tle-new.txt tle.new
```

You may wish to save the previous tle.new to a different filename before doing this. A broad array of satellite orbit classes are represented at this ftp site with ephemeris for each type typically stored in a different text file, e.g., the file goes.txt contains GOES satellite orbit elements. The web site <http://celestrak.com> contains more information on this source.

For AF-GEOSpace Version 1.4 running at 55SWXS, the default element file read at start-up is, \$PLGS_MODELS/MODELS/data/EPHEMERIS/orbel_new.db

This file is created from the satellite orbit elements stored in the ORBEL table of the 55SWXS SAT_DB relational data base and is updated once per day. Satellite names are currently listed as IRON numbers but will be cross-referenced to names, where possible, in the near future.

To read in elements stored in a file other than the default, the user may activate the *Select File* button. A file selection box will open. Choosing the desired file will cause AF-GEOSpace to parse any elements found within the chosen file. Each of these element sets will then be displayed as a satellite selection in the list of parsed elements. The label shown in the list indicates the name of the satellite, the reference time of the elements and the type of element set which was parsed (U = mean element set, X = position-velocity element set).

Auxiliary Input Section

The auxiliary input area is used to specify information such as the reference time of the satellite orbit elements and the time period for which the orbit should be calculated. The information is either input by the user or loaded from the satellite ephemeris files when the *From File* option is used. Specifically, the inputs are:

T_ref:	The reference time of the orbital elements of the satellite, specified in the form DD/MM/YY HH:MM:SS.SSS
T_start, T_stop:	The start and stop time for which the orbit is to be calculated, specified in the form DD/MM/YY HH:MM:SS.SSS. Note that <i>T_start</i> and <i>T_stop</i> must be greater than <i>T_ref</i> .
Time Step:	The time interval with which the orbit is to be calculated. The orbit calculation will go from <i>T_start</i> to <i>T_stop</i> in <i>Time Step</i> increments. The time step is specified in seconds.
Sat. Name:	A mnemonic for the satellite useful for display purposes.
Time Step:	The time step, in seconds, at which the orbit should be calculated.

Links

AF-GEOSpace provides the capability to visualize user-specified satellite-to-ground links. Selecting the *Links...* button will bring up a dialog from which these links can be selected. There are two lists in the dialog: a *Links* list which contains the links associated with the current orbit and a *Stations* list of currently available stations that can be linked. Selecting an item in the *Stations* list will highlight it and display its location just to the right of the *Stations* list. To add this station to the current satellite's *Links* list click on the *Add Link* button in the bottom left of the dialog. When the *Add Link* button is pressed the name of the station will be added to the *Links* list. Any number of links can be added in this manner. To remove a station from the *Links* list, select it and click the *Delete Link* button. To remove all of the stations in the *Links* list click on the *Clear Links* button. Once all of the changes have been made clicking on the *Accept* button will enter the changes and dismiss the dialog. Click the *Cancel* button to dismiss the dialog without entering the changes.

If it is necessary to link to a station that is not in the *Station* list then a new station can be created by clicking on the *Add Station...* button. This will bring up a dialog that allows a new station to be

defined. This dialog has the text fields “Station Name”, “Latitude”, “East Longitude”, and “Altitude(km)”. All four of these parameters must be defined to create a new station. Once these parameters are defined then clicking on the *OK* button will add the new station to the *Station* list and dismiss the dialog. If the *Add Station* dialog is opened but no new station needs to be created, then clicking on the *Cancel* button will dismiss the dialog without creating a new station.

To remove a station from the *Station* list, select the station and click on the *Delete Station* button.

Satellite Detector Field-of-View

To visualize satellite detector fields-of-view, click on the *Detectors...* button. This will bring up a dialog from which the detectors can be chosen. There are two lists in the dialog: a *Devices* list containing all of the devices associated with the current satellite and a *Detectors* list containing just those devices currently activated. Selecting an item in the *Devices* list will highlight it and display its parameters just to the right of the *Devices* list. To add this device to the satellite’s current *Detectors* list, click on the *Add Detector* button in the bottom left of the dialog. When the *Add Detector* button is pressed a compound name consisting of the satellite name and the selected device will be added to the *Detectors* list. To remove a device from the *Detectors* list, select the name of the device in the *Detectors* list and click the *Delete Detector* button. To remove all of the devices in the *Detectors* list click on the *Clear Detectors* button. Once all changes have been made clicking on the *Accept* button will enter the changes and dismiss the dialog. Clicking on the *Cancel* button will dismiss the dialog without updating the changes.

If a desired device is not in the *Devices* list then a new device can be created by clicking on the *Add Device...* button and using the dialog that appears to define the device with the options:

Device Name: Name to appear in the *Devices* list

Detector Type: Two Options: [1] *Fixed Pointing Angle* detectors are specified by a “Detector Pitch Angle (deg)” (zero degrees is nadir pointing) and “Detector Azimuth Angle (deg)” (measured clockwise about nadir, zero azimuth is in the plane containing the nadir and velocity vectors). [2] *Target Tracking* detectors track a location (on the Earth’s surface), defined by the “Target Latitude (N)”, “Target Longitude (E)”, and “Target Altitude (km)”, if location is observable from the satellite. The graphic is turned off when the location is not observable. Tracking detectors have a “:T” appended to their name to allow the user to easily identify them in the *Devices* list.

Detector Field of View (deg): Slider for defining detector field of view (FOV)

To add the new device to the *Devices* list and dismiss the dialog, click the *OK* button. Clicking the *Cancel* button will dismiss the dialog without creating a new device. To remove a device from the *Devices* list, select it and click on the *Delete Device* button.

SATEL Outputs

The SATEL application outputs a 1D Gridded Data Set of the position of the selected satellite as a function of time. Note that for links and detectors to be displayed, they must be associated with the satellite before running the module.

The WBPROD-APP Module

Model Name: Wide-Band Model (WBMOD)
Version: September 1998
Developer: USAF 55SWXS, Air Force Research Laboratory, and Radex, Inc.
References: Secan, J.A., and R.M. Bussey, An Improved Model of High-Latitude F-Region Scintillation (WBMOD Version 13.04), *PL-TR-94-2254* (1994), ADA 288558

Note: It is recommended that AF-GEOSpace users read the original model documentation and descriptive articles before using the models.

WBPROD-APP Overview

The WBPROD-APP application produces a 24-hour forecast of the 95th percentile dB fade levels along user-specified communication link(s) between a receiver site and satellites. The WBMOD climatological ionospheric scintillation model is used and is described in more detail in the WBMOD Science Module section of this User's Manual. In the science module, WBMOD is executed in a transmitter- or receiver-step mode at a fixed time. This application executes WBMOD in a time-step mode with the communication link(s) fixed in location. WBPROD-APP outputs a summary text file of the hourly 95th percentile fades for a specified day of year and ground-to-satellite link. Multiple satellite links to a single ground point can be written to the same file. An option also exists to output a text file with the set of WBMOD parameters for the specified link.

Note: WBPROD-APP does not produce gridded output data for viewing with the AF-GEOSpace graphics modules. This module is a tailored product designed for the 55SWXS to run WBMOD scripts quickly and efficiently. This is an excellent tool for generating scintillation products required for routine customers.

WBPROD-APP Inputs

The following *Run Variables* are mandatory,

Note: This application DOES NOT use the AF-GEOSpace global parameters at the top of the Environment Window, but uses those entered in the text fields appearing below.

Day#: The day of the year, e.g., 1 = 1 Jan and 365 = 31 Dec (for non-leap year).
Kp: The average geomagnetic Kp index forecast for the day.
SSN: The sunspot number forecast for the day.

The following *Station* variables are required to specify the ground station location,

Name: Name of the ground station. If you saved a previous session and wish to re-load it, type in the name of the ground station (exactly as named before) and click on the *Load Script* button (see related discussion below).
Lat (deg N): The geographic latitude of the ground station in degrees North.
Lon (deg E): The geographic longitude of the ground station in degrees East.
Alt (km): The altitude of the ground station above sea level in kilometers.

The following *Satellite* variables are required to specify the locations and communication frequencies for the satellites,

- Name: The satellite name (must be unique).
- Lat (deg N): The geographic latitude of the satellite in degrees North. Remember, this application steps WBMOD in time, the satellite link will be fixed in position.
- Lon (deg E): The geographic longitude of the satellite in degrees East. Remember, this application steps WBMOD in time, the satellite link will be fixed in position.
- Alt (km): The satellite altitude above the center of the Earth in kilometers. Note that this is a different zero point than used when specifying the station altitude. Because the current version of WBMOD does not include doppler effects due to satellite velocity, it is recommended that only geosynchronous satellites be inputted (Alt ~ 36,000 km).
- Freq (MHz): The carrier frequency of the communications signal in MHz.

Once the satellite variables have been input, the satellite must be added to the active satellite list displayed at the bottom of the window by clicking on the *Add Sat to List* button. Additional satellites can then be entered in the variable boxes and added to the list in a similar fashion. Satellites can be deleted from the list by first clicking on the satellite name in the active satellite list and then clicking on the *Delete Sat* button. WBPROD-APP will produce forecasts for all the satellites in the active satellite list.

Before running WBPROD-APP, the *Save Script* button **must be clicked**. This will save the station and satellite parameters in a file labeled stationname.wb, where stationname is the Name entered for the station in the current window.

Previous WBPROD-APP sessions can be loaded by clicking on the *Load Script* button. The file entitled stationname.wb, where stationname is the *Name* entered for the station in the current window will be loaded into WBPROD-APP.

Pressing the *Run Script* button executes WBPROD-APP. The user can choose to have either a *Summary* output (SI index only) or *All* the WBMOD output parameters saved to a file by selecting the appropriate *Text* option before execution.

Note: The *Save Script* button must be clicked before executing WBPROD-APP or else the last saved script will be run.

The *Delete Model* button ends the current WBPROD-APP session and removes WBPROD-APP from the active application modules list.

WBPROD-APP Outputs

WBPROD-APP creates an ASCII text file in the run-time directory and also displays this file in an AF-GEOSpace text window. The following *Text* output file options are available.

- Summary: Creates an ASCII text file labeled stationname_summary, where stationname is the *Name* entered for the station in the current session. This file lists the hourly values of the 95th percentile fades for links from the ground

station to all the satellites in the active satellite list. Fades are reported as negative values (dB).

All: Creates an ASCII text file labeled stationname_all, where stationname is the *Name* entered for the station in the current session. This file lists the hourly values of all the WBMOD output parameters including S4, sigma phi, 95th percentile fade, STDEV LOG(I), and %Time for links from the ground station to all the satellites in the active satellite list. See the *WBMOD Science Module* section of this User's Manual for further details.

The *Display Text* button can be used to view the current output file should it be closed.

Data Modules

Data modules provide methods for reading and plotting data sets produced and formatted external to AF-GEOSpace. The data modules are accessed through the data module manager which becomes visible when the *Data* button under the *Environment Modules* pulldown menu is activated. The data module manager consists of two lists - *Available Data Modules* and *Active Data Modules*. *Available Data Modules* are the modules which are currently supported by AF-GEOSpace. *Active Data Modules* are modules which have been created and used by the AF-GEOSpace user during the current session.

When initially accessed, the data module manager will show a list of data modules under *Available Data Modules*. Since no data modules have yet been created, the *Active Data Modules* list will be empty.

Currently, the following data modules are supported by AF-GEOSpace:

- **DMSP-SPECTRA:** A module to read and plot files containing particle spectra from the DMSP satellite SSJ/4 sensors.
- **HEEM:** A module to read and plot the DMSP High Energy Electron Monitor files derived from the DMSP satellite SSJ/4 data.
- **PIMREAD:** A module to read in the standard output files previously created (i.e., during a different AF-GEOSpace session) by the PIM Science Module.

Running Data Modules

To run a *Data* module, click the mouse on the desired choice under the *Available Data Modules*. For example, to create a new version of the DMSP-SPECTRA module, click the mouse on *DMSP-SPECTRA* in the *Available Data Modules* window. Choosing a data module will do two things: first, the choice is added to the *Active Data Modules* list; second, the options associated with the chosen data module will appear below the data module manager windows. In general, each data module will have a different Environment Window representing the inputs specific to the data module.

The bottom section of the data module window is the same for all data modules. It consists of a status window and buttons for running and deleting the data module, a (deactivated) button to access the grid tool, and a button to allow the data to be saved to a file.

- **Model Status:** The *Model Status* box provides a brief informational message regarding the current state of the data module. Upon creation, the status will be “MODEL INITIALIZED”. If the data module is up-to-date and ready for use by other modules, the message will indicate “MODEL IS READY AND UP TO DATE”. If parameters have been changed since last running the data module, the status box will indicate “PARAMETERS MAY HAVE CHANGED”. Other informational messages may also be displayed depending on the specific data module. A scroll feature is provided for reading longer messages.
- **Run Model:** After setting all of the inputs as desired, the data module may be executed by activating the *Run Model* button. An informational box will appear indicating the data module is running. When completed, the informational box will disappear. At this point, the data generated by the data module is available for use by graphics modules.
- **Delete Model:** If the data module is no longer needed, it may be deleted by selecting the *Delete Model* button.
- **Grid Tool:** Since the grid for data modules is determined by the stored data set and cannot be modified by the user, the *Grid Tool* is deactivated and cannot be accessed when running Data Modules.
- **Save To File:** Data from the data module may be stored to disk in several formats. Activating the *Save To File* button opens a window allowing options on formats and variable choices to be set. The capability to generate ASCII files of user-specified one-dimensional slices of data module data is provided by the COORD-PROBE Graphics Module.

The DMSP-SPECTRA Data Module

Model Name:	DMSP-SPECTRA
Version:	July 1997
Developer:	Air Force Research Laboratory and Radex, Inc.
References:	Brautigam, D.H., M.S. Gussenhoven, and D.A. Hardy, A Statistical Study on the Effects of IMF Bz and Solar Wind Speed on Auroral Ion and Electron Precipitation, <i>J. Geophys. Res.</i> , 96 , 5525-5538 (1991)

DMSP-SPECTRA Overview

The DMSP-SPECTRA data module provides the capability to display electron and ion energy spectra measured by the DMSP SSJ/4 sensors as a function of time. The spectra are determined in the local satellite zenith direction once per second over 20 energy channels spanning the range 30 eV to 30 keV [e.g., Brautigam *et al.* (1991)]. The current version allows the user to choose a DMSP "case" file that contains a data source file created for a specific DMSP satellite orbit and information on estimated equatorward boundaries for event onsets and endings observed during the orbit. There is also an automatic mode that checks the source directory for recent data and, if found, updates the plots.

DMSP-SPECTRA Inputs

To initiate the DMSP-SPECTRA module from the DMSP-SPECTRA Options window the user must click on the *Run Model* button at the bottom of the window. A new window will appear with options for choosing an input data file. The default directory should list the available case files. At 55SWXS these files are automatically written to the AF-GEOSpace directories after each DMSP pass data transmission. For other users, data files are available by request from the Air Force Research Laboratory.

The case files have names of the form case_YY_DDD_TTTT_NNNN where,

YY= Year

DDD= Day of year (1 = 1 Jan, 365 = 31 Dec)

TTTT= UT start time of the orbit in seconds.

NNNN= DMSP satellite ID

To generate a spectra plot and associated listing of events, highlight a case file name and press the *OK* button. The DMSP-SPECTRA module will execute and create both a Special Plot Window displaying the energy spectra and a DMSP-SPECTRA Case Info Window displaying text information on equatorward boundary crossings observed during the orbit.

The user can select the following plotting options by clicking on the *Plot Options* button in the DMSP-SPECTRA Options window:

Data Type: The *Data Type* can be set as either raw *Counts* or *Flux*.

Species: The *Species* options are *Electrons* or *Ions*.

Scale is: This toggle converts between a log (base 10), *LOG10*, and *LINEAR* repre-

sensation of the data. The *AUTO* button sets the minimum and maximum from the measured data. Data at or above the upper limit is colored white. Data at or below the lower limit is colored grey. No data is colored black. For the log scale, zeros are converted to the lower limit and negative numbers are treated as no data.

Input file: The source file name message may be toggled on or off. The name is of the form avej4_NNNN_RRRRRR.cts where NNNN is the DMSP satellite ID and RRRRRR is the Readout orbit number (the higher the orbit number, the more recent the data).

Counts: Min: Max: Tics: The data limits and the number of tics can be set here. The *AUTO* button shows the maximum range from the data file.

Flux: Min: Max: Tics: The data limits and the number of tics can be set here. The *AUTO* button shows the maximum range from the data file.

X axis: This option may be used to set the displayed X axis variable to one of the button parameters, i.e., universal time (*UT*) in seconds, latitude (*Lat*), longitude (*Lon*), universal time in hours:minutes:seconds (*HMS*), or data record numbers (*Recs*). The basic variable is the data record number from which all the other variables are determined. The *Marks* button toggles the event markers on and off.

X UT: Min: Max: Tics: The range of universal time (*UT*) and number of tics to plot are set here. The *ALL* button shows the maximum range obtained from the data file. A UT range of 6400 seconds (~106 min) is plotted by default (*DFLT*).

Y axis: This option may be used to set the displayed Y axis variable to either the energy channel number, i.e., *Bins*, or the energy value, *E(keV)*, corresponding to the channel. The energy channel number is the basic variable. The *ALL* button resets to the widest range.

Y Bins: Min: Max: This parameter may be used to select the channel limits for the plot.

Plot Update: The last generated or selected plot may be updated with this button after a change is made to the plot options.

The following options are also accessible from buttons in the DMSP-SPECTRA Options window:

Display Plot: Brings up the DMSP-SPECTRA Special Plot Window if it has been closed.

Display Text: Brings up the DMSP-SPECTRA Case Info Window if it has been closed.

AUTO MODE: Puts DMSP-SPECTRA into an automatic checking mode. In this mode, DMSP-SPECTRA looks in the directory just above the case directory and if it finds a "check_file" signaling new data it reads and plots the spectra, erases the check_file and waits for the arrival of the next check_file. To exit from the automatic checking mode, type "i" in the *wait* window.

Note: The data directory is set by the environment variable
PLGS_BCSPECTRA_DATADIR.

DMSP-SPECTRA Outputs

The DMSP-SPECTRA module creates both a Special Plot Window displaying the energy spectra and a DMSP-SPECTRA Case Info Window displaying text information on equatorward boundary crossings observed during the orbit.

In the Special Plot Window, the species (electrons or ions), output mode (counts or flux), year, day, and UT range is shown. Below this a 2D color intensity plot of the count rate or flux as a function of energy (or energy channel number) and UT (or any of the other X variable options, i.e., *Lat*, *Long*, *Recs*). The vertical black lines give the location of the equatorward boundaries with the associated numbers corresponding to the estimated quality flag (1 is highest).

The text window shows case file information on the estimated equatorward boundaries for the event. Listed are an event counter called "case" (one entry for each boundary identified in the Special Plot Window), UT (seconds of the day), magnetic local time (MLT in decimal hours) and corrected geomagnetic latitude (MLAT in degrees North), and estimated Kp. The Qe (or Q) index, which represents the boundary position and has a theoretical range of -4 to +12, is calculated from estimated Kp by the formula $Qe = 2 * Kp - 0.35$. The flag variable gives an estimate of the quality of the event (1 is highest).

Note: The effective Kp values determined from the observed MLT and MLAT and recorded in the DMSP-SPECTRA Case Info Window can fall outside of the defined limits for the traditional Kp index, i.e., $Kp = 0.0$ to 9.0 . If this occurs and these MLT and MLAT values are used as direct inputs for the *Use single observation* option of the AURORA science module, an error message will be issued from the AURORA science module. The best resolution is to select the *Use Kp* option in the AURORA science module and set the global Kp value equal to either 0.0 or 9.0 , whichever is appropriate.

In addition to the plots and text output, the DMSP-SPECTRA module creates, for each equatorward boundary found, the corresponding global equatorward boundary curves using the algorithm contained in the Aurora Science Module. These curves are saved as a Field Line Gridded Data Set and can be viewed with the AF-GEOSpace FIELD-LINES graphics module. The corresponding DMSP satellite orbit track is also generated and can be viewed with the SATELLITE graphics module by selecting the "Orbit" option *DMSP-SPECTRA*.

The HEEM Data Module

Model Name:	High Energy Electron Monitor (HEEM)
Version:	October 1996
Developer:	Air Force Research Laboratory
References:	Mullen, E.G., The DMSP SSJ4 Electron Contamination Display: Technical User's Guide, Phillips Laboratory (1996)

Note: It is recommended that AF-GEOSpace users read the original model documentation before using the models.

HEEM Overview

The HEEM data module provides the capability to monitor the activity of radiation belt MeV electrons in near real-time using data from the DMSP satellites. The following description is excerpted from the Technical User's Guide:

"The J4 electron and ion sensors flown on the Defense Meteorological Satellite Program (DMSP) spacecraft starting with F6 were designed to measure electrons and ions from a few tens of eV up to 30 keV. The DMSP auroral particle sensors have provided a wealth of data in this energy range for over twenty years, and these data have been used extensively for scientific investigations and near-real time space weather forecasting to include the auroral oval boundary locations. Using software utilities developed for the Combined Release and Radiation Effects Satellite (CRRES) program, it was discovered that one source of background contamination (removed for low energy particle studies) in the instrument was due to MeV electrons. Using various statistical methods, the MeV electron contamination has been isolated to a level where it can be used qualitatively to determine locations in near-Earth space (between L-values of approximately 1.8 Re and 5 Re) where high fluxes of MeV electrons exist. These energetic electrons are known to correlate with anomalies due to spacecraft charging on some satellites. Correlative studies with dosimeter data from the DMSP F7 spacecraft and high energy electron data from the CRRES satellite were used to make a first order estimate of the electron energies. These flight data comparisons show that the electrons are primarily 2-4 MeV in energy.

Software has been developed to display the data in L-shell (Earth radii at the magnetic equator from the center of the Earth) versus time with the option of showing either daily averages or every DMSP pass. The routine has been added to the AF-GEOSpace package with the option of running orbits through the displays to show when and where the spacecraft encounter high energy outer belt electron populations. A great deal of care has been used to develop algorithms to remove other contamination sources in the raw data, to include sunlight effects. In most cases the data are relatively clean, but great care must be taken to avoid misinterpretation. It should also be remembered that the primary data (30 keV electrons or ions) are also in the displays, and familiarity and interpretation are needed to separate the two distinct (MeV and keV) particle populations. That is why it is recommended that the (MeV) data not be trusted much beyond an L of 5 Re. However, knowing that there is a power law dropoff in high energy electrons from the peak of outer zone to higher L-shells, there is almost certainty that if there are visible counts of high energy electrons at, or above,

an L of 4 Re, then there are sufficient MeV electrons for consideration out to geosynchronous orbits”.

The DMSP SSJ4 sensor data displayed by the HEEM module is automatically processed and written to directories accessible to AF-GEOSpace every time a DMSP data pass is transmitted to 55SWXS. By default, AF-GEOSpace stores 30 days worth of data for HEEM up to the current day. Data from the years 1991 and 1994 are also included in the GEOSpace data directories to be used as examples of conditions at and just after solar maximum, respectively. Examination of the 1991 data shows the creation of a new radiation belt following the 24 March 91 great magnetic storm. The 1994 data includes examples of effects due to recurrent high-speed solar wind streams. Users not at 55SWXS can obtain HEEM data by request from the Air Force Research Laboratory.

HEEM Inputs

The HEEM data module requires the user to specify the following information to determine the desired data set to be viewed.

- | | |
|----------------|---|
| Year: | The year specifying the input data file. |
| Mode: | Select whether the data is to be viewed as <i>Daily Averages</i> or fifteen minute time averages obtained from the DMSP orbit <i>Pass-By-Pass</i> . If you change mode, the default limits on the length of time to be displayed are changed (Defaults: daily averages = last 30 days, pass-by-pass averages = last 2 days). |
| Orbit: | This selection button is used to load a satellite orbit for display in the 2D HEEM display window. The orbit must have been created by the SATEL-APP application module and must have, at least in part, the time interval selected to view the HEEM data. Tags for the HEEM module DMSP input orbits appear in the list but cannot be displayed in the 2D HEEM window. These orbits may be viewed with the <i>SATELLITE</i> graphics module in a regular 2D or 3D Graphics window, where only the last day is shown. |
| Orbit slider: | This slider sets the position of the satellite along the orbit as shown in the 2D HEEM display window. The time corresponding to the slider percentage is displayed below the slider. |
| Satellites: | The user can select to plot data from up to four different DMSP satellites, S1, S2, S3, and S4. The actual satellite names will be displayed at the top of the 2D HEEM display window. Note that there might not always be four DMSP satellites transmitting useful SSJ4 data. If this is the case, and if three satellites are present, the program will desensitize the S4 button. |
| Species: | The species parameter selects between the nominal 30 keV electron (<i>ele</i>) and 30 keV ion (<i>ion</i>) channel. Comparing the output of the two channels will give the user a better feel for the 2-4 MeV electron population that contaminates both. |
| Normalization: | The normalization factors are set to normalize the measurements between the different satellite instruments. Turning this parameter <i>on</i> should result in a slightly smoother plot. |

Background Interpolation: The user can select here whether to fill in the gaps between the measurements displayed in the *Pass-By-Pass* mode. The gaps are replaced with linear interpolates using earlier and later data. The plot will look much smoother if this option is checked *on*. The exact times when there are no measurements will be clear when this option is checked *off*.

Plot Options: Clicking this button gives the following options for viewing the data in the 2D HEEM display window:

Scale: This parameter converts data representation between log to the base 10, *LOG10*, and *LINEAR*. The scale limits on the line below are updated.

Scale Min, Max: The limits to the color bar scale are set here. The *AUTO* button sets the min and max from the measured data. The *DFLT* button restores the default range (Log10: -1 to 2, Linear: 0.1 to 100.). Data at or above the upper limit is colored white. Data at or below the lower limit is colored grey. No data is colored black. For the log scale, zeros are converted to the lower limit and negative numbers are treated as no data.

X Days Min, Max: The day range for the data output is set here. For the *Daily Averages* mode the range can be up to 400 days. For the *Pass-By-Pass* mode the range must be ≤ 5 days. The *ALL* button displays all the days in the currently selected year file. The *DFLT* button displays the last 30 days of data on the file for the *Daily Averages* mode and the last 2 days for the time averages mode. If the days bridge a year boundary (day ≤ 0 or day > 365) the program will check whether the data exists and, if so, will display it, else no data will be shown.

Y LSHELL Min, Max: The L-shell limits for the data output is set here. The *ALL* button selects the maximum allowable range. The *DFLT* button resets to the default range (L=1-6).

Orbit Color: This option specifies orbit color.

Tics: The tics are normally chosen automatically when the plot is created. The user can predetermine the number of tics by clicking the *SET* button and entering the desired number of tics in the appropriate boxes. An exception is the *X Days* tics in the *Pass-By-Pass* mode.

Plot Update: This button updates the HEEM 2D display window. If the HEEM 2D display window is closed, or the model has not been run yet, then the *DISPLAY PLOT* button needs to be pushed after the *Plot Update* is complete.

DISPLAY PLOT: This option pops up the HEEM 2D display window if it has been closed.

Note: The HEEM data file directory is set by the environment variable:
PLGS_BCDMSP_DATADIR

HEEM Outputs

The HEEM data module automatically creates a HEEM 2D display window when executed. At the top of the window the *Species*, *Mode*, *Year* and *Satellites* selected will be displayed.

If the *Daily Averages* mode has been selected the window will contain a 2D color intensity plot of the daily averaged count rate as function of day and L-shell for the time and L-shell intervals selected.

If the *Pass-by-Pass* mode has been selected the window will contain a 2D color intensity plot of the fifteen minute averaged count rate along each DMSP orbit as function of time and L-shell for the time interval and L-shell intervals selected.

If the *Background Interpolation* option has been chosen, data gaps in time will be filled by linear interpolation between earlier and later measurements. Note that HEEM only uses DMSP data taken in a longitude quadrant centered on the South Atlantic Anomaly.

If a satellite orbit has been selected, the L position of the satellite as a function of time will be superimposed on the 2D color intensity plots. The location of the satellite along its orbit is shown by a red square and can be changed by moving the orbit slider.

The PIMREAD Data Module

Model Name: PIMREAD

Version: October 1997

Developer: R. Biasca, Boston College and M. Tautz, Radex, Inc.

PIMREAD Overview

The PIMREAD module creates a AF-GEOSpace 3D Gridded Data Set from a previously produced PIM output file.

PIMREAD Inputs

Select File: Opens a standard file selection box from which to choose the previously produced PIM output file.

PIMREAD Outputs

The PIMREAD data module returns a 3D Gridded Data Set representing the PIM data stored in the specified output file.

Graphics Modules

Graphics modules are used to visualize the data sets created through the Application, Data, and Science modules. The inputs to a graphics module are 1D, 2D, or 3D Data Sets and the outputs are defined as graphical objects. A variety of graphics modules are provided for one-, two-, and three- dimensional visualization. The graphics modules are accessed through the graphics manager which becomes visible when the *Graphics* button under the Environment's Modules pull-down menu is activated. The graphics manager consists of two lists - *Available Graphics Modules* and *Active Graphics Modules*. *Available Graphics Modules* are the modules which are currently supported by AF-GEOSpace. *Active Graphics Modules* are modules which have been created and used by the AF-GEOSpace user during the current session.

When initially accessed, the graphics manager will show a list of graphics under *Available Graphics Modules*. With no graphics yet created, the *Active Graphics Modules* list will be empty.

Currently, the following graphics are supported by AF-GEOSpace:

- **AXES:** Plot a set of axes.
- **COORD-PROBE:** Provides a method for probing data along lines defined in user-specified coordinate systems.
- **COORD-SLICE:** Slice the data set along a constant coordinate direction.
- **DATA-VIEWER:** Provides a means of viewing the model output in a tabular format.
- **EARTH:** Plot an outlined or solid Earth. A variety of additional features are available including Latitude-Longitude grids, locations, and radar fans.
- **FIELD-LINES:** Plot magnetic field lines, flux tubes, and auroral equatorward boundaries.
- **GRID:** Plot the grid associated with a data set.
- **ISOCONTOUR:** Calculate an isocontour of a data set and plot the resulting surface.
- **ORBIT-PROBE:** Plot data sets from along satellite orbits.
- **ORBIT-SLICE:** Cut the data set with a plane placed at the orbital plane of a satellite (or a plane perpendicular to or containing the satellite velocity vector) and plot the resulting slice.
- **PLANE-SLICE:** Cut the data set with an arbitrary plane and plot the resulting slice.
- **SATELLITE:** Provides a means of viewing satellite trajectories, detector cones, and communications links.
- **STARS:** Plot the celestial background including stars, planets, and the moon.

Running Graphics Modules

To run a *Graphics* module, click the mouse on the desired choice in the *Available Graphics Modules* window. For example, to create a new version of the grid, click the mouse on *GRID* in the *Available Graphics Modules* window. Choosing a graphics module will do two things: first, the choice is added to *Active Graphics Modules* list; second, the options associated with the chosen graphics module will appear below the graphics module manager windows. In general, each graphics module will have a different Environment Window representing the inputs specific to the graphics module.

The bottom section of the graphics module window is the same for all graphics modules. The bottom section of the graphics modules displays options for the graphics object. Initially, the bottom section consists of a *Display In:* list used to choose the windows in which to display the graphics object.

AXES

The AXES graphical object will produce a set of AXES for different coordinate systems. It will also produce a vector representing the sun direction, given the current time as set by the UT Global parameter or the Animation Window.

The AXES graphical object rendering is dependent on the window type.

In a 1D window, the AXES graphical object does nothing.

In a 2D window, the AXES graphical object plots lines representing Y and Z axes with the origin at the point where the Greenwich Meridian crosses the equator (0 deg Long, 0 deg Lat). The Z axis points north and the Y axis points east.

In a 3D window, the AXES graphical object plots lines representing X, Y, and Z axes with the origin at the center of the Earth.

The AXES graphical object supports the *Window* and *Clipping* options.

AXES Inputs

Axes Frame:	The coordinate system in which the axes should be aligned. Choices are:
GEOC:	Geocentric coordinate system axes: The Z axis (blue) is aligned with the north rotational pole, the X axis (red) pierces the Greenwich Meridian on the equator (0 deg Long, 0 deg Lat), and the Y axis (green) is equal to the negative of the cross-product of X and Z.
GSM:	Geocentric solar magnetospheric coordinate system axes: The X axis (red) points to the Sun. The Z axis (blue) is perpendicular to X and lies in the plane containing the magnetic dipole axis. The Y axis (green) completes the right handed system and is positive towards dusk.
SM:	Solar magnetic coordinate system axes: The X axis (red) is perpendicular to Z and lies in the plane containing the Z axis and the Earth-Sun line. The Z axis (blue) is coincident with the magnetic dipole axis. The Y axis (green) completes the right handed system and is positive towards dusk.
GEI:	Geocentric equatorial inertial coordinate system axes: The Z axis (blue) is the same as for the <i>GEOC</i> coordinate system. The X axis (red) is aligned along the vernal equinox. The angle between the vernal equinox and the Greenwich Meridian is set by the current UT from the Animation Window.
Sun vector:	Solar direction axis: The direction of the sun (yellow) is based on the current UT from the Animation Window.

Length:	The length of the axis to be drawn. Units are Earth radii (R_e).
Show Axes:	For each of the axis components, activating the <i>Show Axes</i> toggle button makes the axis visible.
Show Tics:	For each of the axis components, activating the <i>Show Tics</i> toggle button makes the tick marks on the axis visible.
Major Tic Spacing:	The spacing (in R_e) at which major tick marks should be drawn.
Minor Tic Spacing:	The spacing (in R_e) at which minor tick marks should be drawn.

COORD-PROBE

The COORD-PROBE graphical object is used to produce a line plot through a data set. The line variable may be specified along a given coordinate direction in one of several coordinate systems.

The COORD-PROBE graphical object rendering is dependent on the window type.

In a 1D window, the COORD-PROBE graphical object produces a line plot.

In a 2D window, COORD-PROBE will project the line through the data set onto a 2D grid of longitude (horizontal) and latitude (vertical).

In a 3D window, COORD-PROBE will display the line through the data set in three-dimensional space around the Earth.

The COORD-PROBE graphical object supports the *Window*, *TransformXY*, and *IDOptions* options.

COORD-PROBE Inputs

Data:	This option menu is used to select the main data set the COORD-PROBE is to be taken through. This option must be set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.
System:	The coordinate system in which the coordinate line will be generated. The user may select to probe the data set in geocentric (GEOC), geocentric solar magnetospheric (GSM), solar magnetic (SM), or geocentric equatorial inertial (GEI) coordinates.
Geometry:	Specify the geometry in which the coordinate line will be generated. The user may select cartesian, cylindrical, or spherical geometry.
Vary:	Specify the coordinate along which the probe is to vary. These options will change depending on the settings of the <i>Data</i> , <i>System</i> , and <i>Geometry</i> inputs.
Coordinate 1:	(the label will change depending on the <i>Data</i> , <i>System</i> , and <i>Geometry</i> settings) The value of the first independent coordinate variable for which the probe line is to be generated (for a radial probe, this specifies the fixed value of the latitude (deg N); etc.)
Coordinate 2:	(the label will change depending on the <i>Data</i> , <i>System</i> , and <i>Geometry</i> settings) The value of the second independent coordinate variable for which the probe line is to be generated (for a radial or latitude probe, this specifies the fixed value of the longitude (deg E); for a longitude probe, this specifies the fixed value of the latitude (Deg N); etc.)
Probe Minimum:	(the label will change depending on the <i>Data</i> , <i>System</i> , and <i>Geometry</i> settings) The minimum value of the dependent coordinate variable for which the probe line is to be generated.
Probe Maximum:	(the label will change depending on the <i>Data</i> , <i>System</i> , and <i>Geometry</i> settings) The maximum value of the dependent coordinate variable for which

the probe line is to be generated.

Steps: The number of points along the coordinate variable at which the data set is to be sampled.

Save To File: Save current 1D variables to a file.

COORD-SLICE

The COORD-SLICE graphical object is used to produce a slice or surface through a data set. The slice is produced along a constant of one coordinate direction. For example, if the data set was produced on a spherical grid, the COORD-SLICE graphical object can produce slices at constant radius, constant latitude, or constant longitude. If the data set was produced using a cartesian grid, the COORD SLICE graphical object could produce a slice at constant X, Y, or Z value.

The COORD-SLICE graphical object rendering is dependent on the window type.

In a 1D window, the COORD-SLICE graphical object does nothing.

In a 2D window, COORD-SLICE will project the constant coordinate slice onto the Earth's surface. Note that for this to be meaningful, the slice should be produced at constant altitude on a spherical grid.

In a 3D window, COORD-SLICE will display the coordinate slice through the data set in three-dimensional space around the Earth.

The COORD-SLICE graphical object supports the *Window*, *Clipping*, *Transform*, and *Transparency* options.

COORD-SLICE Inputs

- Data:** The *Data* option menu is used to select the main data set the COORD-SLICE is to be taken through. This option must be set to a data set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.
- Orbit:** The *Orbit* option may be used to slave the position of the coordinate slice to the position of a satellite along its orbit. The option menu contains a list of valid, previously produced orbits.
- Coordinate:** The *Coordinate* option defines the constant coordinate from the choices *C0*, *C1*, and *C2*. The generic names represent specific coordinate choices depending upon the grid type of the data set. For example, if the grid type of the data set is spherical, *C0* will produce a slice at constant radius; *C1* will produce a slice at constant latitude; *C2* will produce a slice at constant longitude. Similarly, if the data set has a cartesian grid, the *C0*, *C1*, and *C2* will produce slices at constant X, Y, and Z, respectively.
- Position Value:** The *Position Value* option determines the position of the coordinate slice. If the COORD-SLICE is not slaved to an orbit, the position value represents the position along the constant coordinate. For example, if the dataset has a spherical grid and the *C0* coordinate is chosen, COORD-SLICE will produce a slice at constant radius. The position value input will select the value of the radius at which to produce the slice. The value will range from the grid minimum to the grid maximum for the chosen coordinate.
- Number of Contours:** The *Number of Contours* input slider determines the number of contour lines to be plotted between the data minimum and the data maximum if the *Rendering Type* selection is *Lines: White* or *Lines: Color* (see below).

Rendering Type:	The <i>Rendering Type</i> field will allow the COORD-SLICE to be filled as colored or white contours, filled or discrete. Any combination of the options may be selected.
Fill:	Render the COORD-SLICE as solid, filled, color contours.
Lines: White	Render the COORD-SLICE as discrete white lines. The lines represent isovalues of the data evenly spaced between the data minimum and the data maximum. The number of contours is determined by the <i>Number of Contours</i> input.
Lines: Color	Similar to <i>Lines: White</i> , but the isovalue lines are colored according to the color bar to represent the magnitude of the isovalue.
Show Gray:	If the grid extends beyond meaningful data in the data set, the points without valid data will be filled in as gray if this option is turned on.
Show Data:	The data will be contoured if this option is turned on.
Show Grid:	An outline of the grid will be shown if this option is turned on.

DATA-VIEWER

The DATA-VIEWER graphical object is not a true graphical object, but does provide an interface to view a data set. It provides a means of viewing a data set in a formatted, tabular output form.

In order to view three-dimensional data sets in a two-dimensional tabular format, the DATA-VIEWER allows the user to assign one dimension of the dataset to the columns and another dimension to the rows of the tabular output. The third dimension is then chosen through a scroll bar. The scrollbar chooses the "slice" at which the rows and columns are extracted from the three-dimensional data set.

The DATA-VIEWER graphical does not render into any plotting window.

The DATA-VIEWER graphical object does not support options.

DATA-VIEWER Inputs

- | | |
|----------|---|
| Data: | This option menu is used to select the data set to be viewed. |
| Columns: | This switch is used to determine which coordinate of the data set should be represented by columns in the tabular output. For example, if the grid type of the data set is <i>Spherical</i> , and <i>Columns</i> is set to <i>C0</i> , each column of the tabular output will represent data at a constant radius. |
| Rows: | This switch is used to determine which coordinate of the data set should be represented by rows in the tabular output. For example, if the grid type of the data set is <i>Spherical</i> , and <i>Rows</i> is set to <i>C1</i> , each row of the tabular output will represent data at a constant latitude. |
| Z: | This switch is used to determine which coordinate of the data set should be controlled by the scrollbar in the tabular output. For example, if the grid type of the data set is <i>Spherical</i> , and <i>Z</i> is set to <i>C2</i> , the scroll bar to the right of the <i>Z</i> switch will change the longitude of the data shown in the tabular output section. By moving the scroll bar, the user can view different "slices" of three-dimensional data sets. The value of the position set by the scroll bar is shown in the upper left hand corner of the tabular display. |

EARTH

The EARTH graphical object can be used to plot a representation of the Earth as well as surface grids, locations, and various emitters. Rendering of the EARTH graphical object is dependent on the window type.

In a 1D window, the EARTH graphical object does nothing.

In a 2D window, the EARTH graphical object plots outlines or solid representations of the Earth's continents. The horizontal axis is longitude; the vertical axis is latitude.

In a 3D window, the EARTH graphical object plots a sphere with either outlines or filled representations of the Earth's continents.

The EARTH graphical object supports the *Window*, *Clipping*, *Lighting*, *Material*, and *Transparency* options.

EARTH Inputs

Outline Detail: The user can select any of the buttons in this section to determine how the Earth is drawn. The choices are:

Filled: Draw the continents filled.

Geographic Bndys: Draw white outlines of geographic boundary features.

Political Bndys: Draw white outlines of political boundaries.

Rivers: Draw white outlines of rivers.

Locations: Draw locations on or above the Earth as specified in the *Location* dialog box (see below).

Grid Options: The selections within this section allow the user to place several different grids on the representation of the Earth. The choices are:

Lat/Lon Labels: Show labels on geographic latitude and longitude grid lines generated by *Lat/Lon Grid* option (see below).

Lat/Lon Grid: Render a grid showing geographic latitude and longitude. The default resolution is 20° (i.e., *Lat Res* = 10 and *Lon Res* = 10).

Mag Dipole Grid: Render a grid showing magnetic latitude and longitude of the tilted dipole field. The default resolution is 20° (i.e., *Lat Res* = 10 and *Lon Res* = 10).

CGM Grid: Render a grid showing magnetic latitude and longitude of the CGM field. The default resolution is 10°.

Terminator: Draw a line at the terminator using the global UT.

Resolution: This slider determines the resolution with which outline features are rendered and becomes higher as the slider value is decreased. This slider only affects outlined geographic boundaries, political boundaries, and rivers.

Detail Level:	The database from which the outline features are rendered on the Earth is divided by “detail level”. As <i>Detail Level</i> is increased, more minor geographic features are included on the plot. For example, with geographic boundaries, a detail level of one will render continents and “major” islands. As detail level is increased, and increasing number of “minor” islands and other small geographic features will be included in the output. This slider only affects outlined geographic boundaries and rivers.
Lat Res, Lon Res:	Number of steps (including the poles) used to divide latitude and longitude. Note that these do not affect the <i>CGM Grid</i> display.
Colors:	Opens a pop-up dialog box for choosing the color of each feature available in the Earth Module.
Locations:	<p>With this pop-up dialog box the user can choose what stations should be displayed as locations on or above the Earth. The left half of the dialog contains a scrolled list of the available stations. A station that is currently being displayed (provided the <i>Locations Outline Detail</i> is chosen) will have an asterisk in front of the name. The altitude, latitude, and longitude of the selected station are shown in the upper right hand side of the dialog.</p> <p>To display a station, highlight it by clicking on it in the <i>Stations</i> list and click the <i>Add</i> button. An asterisk will be placed in front of the highlighted name to indicated that this station is currently being displayed. The next time the graphics window updates the newly added station will show up. To remove a station from being displayed, highlight the name of the station as above and click on the <i>Remove</i> button. The asterisk that was in front of the station name will be removed and the next time the graphics window updates the name of the station will not be displayed.</p> <p>To add a station to the <i>Stations</i> list click on the <i>Create...</i> button and a dialog with text boxes appears for entering the “Label” for the station name, “Altitude(Km)”, “Lat(N)” for North Latitude, and “Lon(E)” for East Longitude. A station is typically named after its location, e.g., Cleveland.</p> <p>Once all attributes have been specified, the <i>Accept</i> button can be clicked to dismiss the dialog and the newly specified label will now appear in the scrolled list. Scrolling may be necessary to see the new label. By default the new station is set to be displayed in the graphics window. If the user has brought up the dialog to add a new station but decides against doing so the <i>Cancel</i> button can be clicked to simply dismiss the dialog box.</p> <p>An item in the station list can be completely removed by highlighting the item and then clicking on the <i>Delete</i> button. The location dialog can be dismissed by clicking the <i>Done</i> button in the lower right hand corner.</p>
Emitter:	This pop-up dialog box is used to select the emitters to be displayed. An emitter can be one of two types: radar (<i>RADAR</i>) or communication (<i>COMM</i>). The left half of the dialog contains a scrolled list of the available emitters and their locations. An emitter that is currently being displayed (provided the <i>Locations Outline Detail</i> is chosen) is marked by an asterisk.

To display an emitter, select it by clicking on it in the scrolled *Emitters* list. It will then be highlighted and its attributes (type, range, azimuth and elevation limits) displayed in the upper right hand corner of the dialog. Click the *Add* button and an asterisk will be placed in front of the highlighted name to indicate that this emitter is currently being displayed. The next time the graphics window updates, the newly added emitter will be displayed. To remove an emitter from being displayed, highlight the name of the emitter as above and click the *Remove* button. The asterisk that was in front of the emitter name will be removed and the next time the graphics window updates, the emitter will not be displayed.

The *Appearance Options* section controls the display of the emitter itself. The *Solid* and *Wire Frame* toggle buttons allow both the emitter sides and end cap to be displayed as solid objects or as outlines, respectively. If both options are selected then both are displayed. The *Wire Frame Spacing* slider controls the resolution at which the emitter is displayed. At a low resolution the emitter may appear “blocky”, but it takes a relatively short time to redraw the emitter. With a higher resolution the emitter will appear smooth but may take longer to redraw. The *Transparency Alpha Value* slider controls how transparent/opaque the emitter appears; where a value of 1.0 is fully opaque and a value of 0.0 is fully transparent. To change the color of the emitter select the *Color...* button below the *Transparency* slider. This brings up the standard color editor dialog. Finally, for selected options to take affect, click the *Apply* button and the next time the window updates the emitter will appear as described in the *Appearance Options* section.

The *Done* button is used to dismiss the dialogue.

The *Create...* button brings up a new dialog box for creating an emitter. The *Emitter Station ID* list contains the names of the available locations where the emitter can be placed. If a new location is needed select the *Create Station...* button in the upper right hand side of the dialog. This will bring up the dialog used to create a station. (See the *Locations* section above on how to use this dialog.) To the right of the *Emitter Station ID* list are several fields that define the emitter. The “Emitter Name” text field allows the new emitter name to be entered. This name should be unique to avoid confusion. The *Type* option menu allows the emitter to be designated for radar (*Radar*) or communications (*Comm*). Define the emitter using the text fields “Range (Km)”, “Azimuth Limits (Deg)”, and “Elevation Limits (Deg)”. After defining the emitter, the *Accept* button is used to created the emitter and place its location and name in the *Emitters* list. By default the new emitter will be displayed in the graphics window. If a new emitter should not be created, the *Cancel* button from the emitter creation dialog box can be selected to dismiss the dialog without creating a new emitter.

Note: Files with lists of stations (stations.dat) and emitters (emitters.dat) that can be directly edited are located in the directory \$PLGS_MODELS/MODELS/data/STATIONS

FIELD-LINES

The FIELD-LINES graphical object is used to produce a depiction of magnetic field lines from various models and the equatorial boundary produced by the DMSP-SPECTRA and AURORA modules.

The FIELD-LINES graphical object rendering is dependent on the window type.

In a 1D window, the FIELD-LINES graphical object does nothing.

In a 2D window, FIELD-LINES will project the lines onto a 2D grid of longitude (horizontal) and latitude (vertical).

In a 3D window, FIELD-LINES will display the lines in three-dimensional space around the Earth.

The FIELD-LINES graphical object supports the *Window*, *Clipping*, *Lighting*, *Material*, and *Transparency* options.

FIELD-LINES Inputs

Data:	The <i>Data</i> option menu is used to select the main data set and the type of field lines to be displayed. This option must be set before rendering is allowed. The option menu contains a list of valid, previously generated <i>BFIELD-APP</i> items.
Choose Color:	The color popup menu enables one to color the field lines.
Plot Type:	The plot type field determines how the FIELD-LINES should be rendered.
Field Lines:	Render the FIELD-LINES as separate field lines.
Filled Surface:	Render the FIELD-LINES as a surface connecting the field lines.
Field Line Width:	This slider is used to select the width of the field lines in the display from 1 (thinnest) to 5 (thickest).

GRID

The GRID graphical object can be used to draw the calculation grid for the dataset. Rendering of the GRID graphical object is dependent on the window type.

In a 1D window, the GRID graphical object does nothing.

In a 2D window, the GRID graphical object plots the grid of the dataset with the horizontal axis representing longitude and the vertical axis representing latitude.

In a 3D window, the GRID graphical object draws the grid of the data set in three-dimensional space.

The GRID graphical object supports the *Window* and *Clipping* options.

GRID Inputs

Data: The *Data* option menu is used to select the main data set for which the GRID is to be plotted. This option must be set to a data set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.

Plot as: This input is used to specify whether the grid should be plotted as a series of *Points*, one to a grid vertex, or as a series of connected *Lines*.

ISOCONTOUR

The ISOCONTOUR graphical object is used to produce a surface of constant value through a three dimensional data set.

The ISOCONTOUR graphical object rendering is dependent on the window type.

In a 1D window, the ISOCONTOUR graphical object does nothing.

In a 2D window, ISOCONTOUR will project the constant value surface onto a 2D grid representing longitude (horizontal) and latitude (vertical).

In a 3D window, ISOCONTOUR will display the constant value surface through the data set in three-dimensional space around the Earth.

The ISOCONTOUR graphical object supports the *Window*, *Clipping*, *Material*, *Transform*, *Lighting*, and *Transparency* options.

ISOCONTOUR Inputs

Data: The *Data* option menu is used to select the main data set the ISOCONTOUR is to be taken through. This option must be set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.

Contour Value: The *Contour Value* slider input determines the value of the constant surface. The values will range from the minimum to the maximum for the chosen data set. The number below the slider represents the actual data value.

ORBIT-PROBE

The ORBIT-PROBE graphical object is used to produce a line plot through a data set along an orbit.

The ORBIT-PROBE graphical object rendering is dependent on the window type.

In a 1D window, the ORBIT-PROBE graphical object produces a line plot.

In a 2D window, ORBIT-PROBE does nothing.

In a 3D window, ORBIT-PROBE does nothing.

The ORBIT-PROBE graphical object supports the *Window*, *TransformXY*, and *IDOptions* options.

ORBIT-PROBE Inputs

Path/Abscissa:	This option menu is used to select an orbit from a list of valid, previously produced orbits.
Data/Ordinate:	This option menu is used to select the main data set the ORBIT-PROBE is to be taken through. This option must be set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.
Position:	The <i>Position</i> slider input determines the position along the orbit.
Save To File:	This option saves the current 1D variables to a file.

ORBIT-SLICE

The ORBIT-SLICE graphical object is used to produce a slice or surface through a data set. The slice is produced in the plane of a specified orbit (or in a plane perpendicular to or containing the satellite velocity vector).

The ORBIT-SLICE graphical object rendering is dependent on the window type.

In a 1D window, the ORBIT-SLICE graphical object does nothing.

In a 2D window, ORBIT-SLICE will project the slice onto the Earth's surface. Although allowed, usually this is not meaningful.

In a 3D window, ORBIT-SLICE will display the slice through the data set in three-dimensional space around the Earth.

The ORBIT-SLICE graphical object supports the options *Window*, *Clipping*, *Transform*, and *Transparency*.

ORBIT-SLICE Inputs

Data:	The <i>Data</i> option menu is used to select the main data set the ORBIT-SLICE is to be taken through. This option must be set to a data set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.
Orbit:	The <i>Orbit</i> option is used to slave the position of the slice to the position of a satellite along its orbit. This option must be set to an orbit before rendering is allowed. The option menu contains a list of valid, previously run orbits.
Position Value:	The <i>Position Value</i> option determines the position along the orbit at which to draw the slice.
Number of Levels:	The <i>Number of Levels</i> input slider determines the number of contour lines to be plotted between the data minimum and the data maximum if the <i>Rendering Type</i> selection is <i>Lines: White</i> or <i>Lines: Color</i> (see below).
Rendering Type:	The <i>Rendering Type</i> field will allow the ORBIT-SLICE to be filled as colored or white contours, filled or discrete. Any combination of the options may be selected.
Fill:	Render the ORBIT-SLICE as solid, filled, color contours.
Lines: White	Render the ORBIT-SLICE as discrete white lines. The lines represent isovalues of the data evenly spaced between the data minimum and the data maximum. The number of contours is determined by the <i>Number of Levels</i> input.
Lines: Color	Similar to <i>Lines: White</i> , but the isovalue lines are colored according to the color bar to represent the magnitude of the isovalue.

	Show Gray:	If the grid extends beyond meaningful data in the data set, the points without valid data will be filled in as gray if this option is turned on.
	Show Data:	The data will be contoured if this option is turned on.
	Show Grid:	An outline of the grid will be shown if this option is turned on.
Orbit Planes:	The <i>Orbit Planes</i> toggle switches determine which orbital planes are rendered. The choices are:	
	P0:	Draws a plane containing the inertial orbital plane of the satellite.
	P1:	Draws a plane at the satellite position and perpendicular to the satellite velocity vector.
	P2:	Draws a plane at the satellite position that contains the satellite's velocity vector and is perpendicular to the inertial orbital plane.

PLANE-SLICE

The PLANE-SLICE graphical object is used to produce a planar slice through a data set. The orientation of the slice is set by two user specified rotations.

The PLANE SLICE graphical object rendering is dependent on the window type.

In a 1D window, the PLANE-SLICE graphical object does nothing.

In a 2D window, the PLANE-SLICE graphical object does nothing.

In a 3D window, PLANE-SLICE will display the planar slice through the data set in three-dimensional space around the Earth.

The PLANE-SLICE graphical object supports the *Window*, *Clipping*, *Transform*, and *Transparency* options.

PLANE-SLICE Inputs

Data:	This option menu is used to select the main data set the PLANE-SLICE is to be taken through. This option must be set before rendering is allowed. The option menu contains a list of valid, previously run science, data, and application data sets.
Rotate-X:	The <i>Rotate-X</i> input slider rotates the position of the planar slice around the current Z axis.
Rotate-Y:	The <i>Rotate-Y</i> input slider rotates the position of the planar slice around the current Y axis.
Translate-X:	The <i>Translate-X</i> input slider translates the position of the planar slice along the direction perpendicular to the current position of the plane, as set by the rotation sliders.
Number of Levels:	The <i>Number of Levels</i> input slider determines the number of contour lines to be plotted between the data minimum and the data maximum if the <i>Rendering Type</i> selection is <i>Lines: White</i> or <i>Lines: Color</i> (see below).
Rendering Type:	The <i>Rendering Type</i> field will allow the PLANE-SLICE to be filled as colored or white contours, filled or discrete. Any combination of the options may be selected.
Fill:	Render the PLANE-SLICE as solid, filled, color contours.
Lines: White	Render the PLANE-SLICE as discrete white lines. The lines represent isovalues of the data evenly spaced between the data minimum and the data maximum. The number of contours is determined by the <i>Number of Levels</i> input.
Lines: Color	Similar to <i>Lines: White</i> , but the isovalue lines are colored according to the color bar to represent the magnitude of the isovalue.

- Show Gray: If the grid extends beyond meaningful data in the data set, the points without valid data will be filled in as gray if this option is turned on.
- Show Data: The data will be contoured if this option is turned on.
- Show Grid: An outline of the grid will be shown if this option is turned on.

SATELLITE

The SATELLITE graphical object is used to view a satellite trajectory and associated detector cones and communications links. The trajectory can be colored with interpolated values from a selected data set. The orbit trajectory, detector cones, and communications links must have been produced previously using the SATEL-APP application module.

The SATELLITE graphical object rendering is dependent on the window type.

In a 1D window, the SATELLITE graphical object does nothing.

In a 2D window, the SATELLITE will project the trajectory onto a 2D grid representing longitude (horizontal) and latitude (vertical).

In a 3D window, the SATELLITE will display the trajectory in three-dimensional space around the Earth.

The SATELLITE graphical object supports the *Window* and *Clipping* options.

SATELLITE Inputs

Orbit: This option menu is used to select the SATELLITE orbit. This option must be set before rendering is allowed. The option menu contains a list of valid orbits produced previously using the SATEL-APP application module.

Data: This option menu is used to select a main data set for display along the SATELLITE trajectory. The option menu contains a list of valid, previously run science, data, and application data sets. When a data set is selected, the orbit should appear colored, representing interpolated data values along the track. If the *Data* option is off, the orbit trajectory appears as a single color.

Label: The label specifies the nature of the text written at the current position of the satellite. The available labels are:

Sat Name: The satellite name tag, set when it was created.

Rad, Lat, Lon: The satellite position in spherical coordinates.

X, Y, Z: The satellite position in Cartesian coordinates.

Data Value: The interpolated data value at the satellite position.

Time: The current time, from the *Satellite position (%)* slider.

Pop Marker: By default, if a marker is displayed, it will be positioned based on the satellite's three-dimensional location. It may be obscured by other objects. If the *Pop Label* toggle is on, the label will always be rendered in front of all other objects and will therefore always be visible.

Satellite position (%): The position along the selected orbit. The value is percentage of UT with respect to the minimum and maximum UT of the orbit. A small red sphere depicts the current position of the satellite. Note that the slider position setting is overridden when the animation feature is selected (see Plotting Windows section of the documentation).

Step: The arrows increment the orbit forward or backward by one UT step.

The *Detector Options* section allows the user to select the detector and links to display for this satellite as well as adjust viewing characteristics:

- Cone Color: This option enables one to color the detector cone in an arbitrary way.
- Orbit Color: This option enables one to color the orbit in an arbitrary way.
- Detectors: This button brings up a dialog that contains a list of the available detectors for this satellite. Those detectors that are highlighted will be displayed. Clicking on the detector name will highlight/unhighlight the detector. The *Done* button is used to dismiss the dialog.
- Links: This button brings up a dialog that contains a list of the available links for this satellite. For the highlighted links, when the satellite is in line-of-sight of the link a line is drawn between the satellite and the link. Clicking on the link name will highlight/unhighlight that link. The *Done* button is used to dismiss the dialog.
- Solid Detector: This toggle button is used to display solid detector cones. By default only the silhouette edges of the detector cones are displayed.

The *Reference Frame* section determines how the SATELLITE orbit should be rendered. The two coordinate options are geocentric (GEOC) and Earth centered inertial (ECI).

- Geocentric: Render the SATELLITE orbit in geocentric (GEOC) coordinates. Since these coordinates are rigidly attached to the spinning Earth and represent a non-inertial frame, the trajectory will not be approximately elliptical in shape.
- Inertial: Render the SATELLITE orbit in Earth centered inertial (ECI) coordinates. Here the trajectory will have an approximately elliptical shape. Note that the position of the orbit rotates when animation is selected because the inertial orbit plane is not fixed in geocentric coordinates.

The SATELLITE object has a special Graphics Module Option denoted as *Marker*. Clicking on the *Marker* button brings up sliders that allow the user to specify the radius and resolution of the satellite marker.

STARS

- References:
- Chapront-Touze, M., and J. Chapront, *Astron. Astrophys.*, 124, 50 (1983)
 - Hoffleit, D., and W.H. Warren, Jr., *The Bright Star Catalogue*, Astronomical Data Center, NSSDC/GSFC (1991)
 - Montenbruck, O., and T. Pfleger, *Astronomy on the Personal Computer*, Springer-Verlag, 1991.
 - Simon, J.L., P. Bretagnon, J. Chapront, M. Chapront-Touze, G. Francou, and J. Laskar, *Astron. Astrophys.* 282, 663 (1994)

STARS Overview

The STARS graphical object renders the celestial background as seen from the Earth for a given date and time. Stars as dim as visual magnitude eight, the planets, and the moon can be represented with this module. This module uses the Yale Bright Star catalogue, compiled by D. Hoffleit, as a stellar data base. Apparent equatorial coordinates are computed for the equinox of date from J2000 catalogued positions; these are corrected for stellar proper motion as well as the precession and nutation of the Earth. Lunar and planetary positions are computed from the FORTRAN codes ELP82B and PLANETAP, as obtained from the Astronomical Data Center of Goddard Space Flight Center. Apparent planetary positions in the Earth's frame of reference are corrected for precession and nutation.

The STARS graphical object can be plotted in either a 2D or 3D window. In a 2D window the STARS graphical object plots (select squares, RA-DEC grid) a flat projection of the celestial sphere as seen from the Earth, with Right Ascension increasing in the horizontal direction from left to right, and Declination increasing from -90 to +90 degrees as one moves vertically.

In a 3D window, the STARS graphical object plots the celestial sphere as a 3-dimensional background to the near-Earth space environment. An option exists to plot this background as a 3-dimensional sphere of varying radius.

The STARS graphical object supports the *Windows*, *Lighting*, *Material*, and *Clipping* options.

STARS Inputs

The STARS graphical module requires the following inputs:

- Detail:
- The user can select buttons in this section to determine which objects are drawn in the celestial sphere. The choices are:
 - Stars: Locate and draw the stars as white squares.
 - Stars:color: Plot stars in color instead of white. Rendered colors are based on stellar spectral classification type (OBAFGKM) and are approximately those seen by the human eye from the Earth's surface.
 - Stars:circle: Plot stars as circles instead of squares.
 - Sun: Locate and draw the Sun.
 - Planets: Locate and draw the eight major planets. Planets are

color coded shaded spheres, and are approximately the colors seen by the human eye through a small telescope - Mercury and Venus are white, Mars is red, Jupiter is a sandy brown, Saturn is yellowish, Uranus is aquamarine while Neptune is a dark turquoise.

Moon: Locate and draw the Earth's moon. Plotted as a white shaded sphere and is drawn to the same scale as the Earth 3D object.

Grid Options: Several types of grids may be placed upon the surface of the celestial sphere. An option to output positions of the moon and planets is included in this section. The options are:

Lat/Lon Grid: Render a grid showing geographic latitude and longitude upon the celestial sphere. The local sky for an observer at a given latitude and longitude can thus been determined. The resolution is ten degrees.

RA/DEC Grid: Render a grid showing Right Ascension and Declination of the background celestial sphere. Resolution is ten degrees.

Ephem. Output: When enabled in conjunction with either the *Planets* or *Moon* toggle button, this button will output planetary and lunar positions to standard output for the input date and time. Estimated precision is better than 10 seconds of arc for the period 1980 - 2000.

Maximum Magnitude: This slider selects the visual stellar maximum magnitude (or minimum brightness) that will be plotted from the data base (magnitude eight corresponds to minimum brightness setting). A total of 9110 stars are catalogued in this data base. Relative brightness is modeled within the code by adjusting the pixel size and RGB color intensity of a plotted star, and corresponds approximately to the visual magnitude as catalogued in the Yale data base.

Maximum Size(pixels): This slider controls the maximum pixel size used to plot the brightest star, i.e., Sirius. Down to an area of one pixel, the brightness of the star is represented by the size of the star in pixels. Below one pixel size, we reduce the intensity of the individual pixel. Thus, the larger the value of the maximum pixel size, the dimmer the star that will be visible in the window.

Finite Radius: Plot stars on the surface of a sphere with a radius determined by the *Celestial Radius* slider.

Celestial Radius: The radius of the celestial sphere, in Earth radii, can be adjusted with this slider.

R=Infinity: Plot stars in a perspective view, i.e., an arbitrarily large celestial sphere is used within which the viewer is effectively contained.

Graphical Module Options

This section describes the visualization controls and options available when running graphics modules. These options typically appear as buttons on the right side of each Graphics Module window and are controlled using sets of option buttons that appear at the bottom of the window.

The following options are currently supported in AF-GEOSpace,

- **Controls:** Options appearing in all Graphics Modules that control On/Off, Updating, and Deletion of graphical objects.
- **WINDOWS:** Select the window to display a graphical object.
- **CLIPPING:** Apply clipping planes to a graphical object.
- **LIGHTING:** Model the effect of light on a graphical object.
- **MATERIAL:** Modify the light reflection properties of a graphical object.
- **TRANSFORM:** Set limits or functionally transform a 2D or 3D data set.
- **TRANSFORMXY:** Set limits/functionally transform the domain and range of a 1D data set.
- **TRANSPARENCY:** Control the degree of transparency of a graphical object.
- **1D OPTIONS:** Set specialized parameters for a 1D line plot.
- **MARKER:** Set the size and resolution of a sphere representing the satellite.

Controls

The graphics controls appear on all graphical objects. They consist of buttons labeled *Update*, *On (Off)* and *Delete*. The function of each of these buttons is given below.

- Update: The *Update* button forces this graphical object to be rebuilt and replotted. Usually it is not necessary to force the object to be rebuilt when options have been changed. This is not true, however, when the data set or slave data set is changed. In these cases, an explicit update of the model is required. Depending on the graphics module, other cases may also require an explicit update for the model to be rebuilt.
- On (Off): The *On (Off)* button determines whether the graphical object is displayed in a plot. It provides a convenient method for temporarily stopping the display of the object. If you do not want the object displayed in any plot, turn the object to *Off*. To re-display the object in the same plots, turn the object *On*.
- Delete: The *Delete* button destroys the graphical object. It should only be used when a graphical object is no longer needed. Deleted graphical objects can not be undeleted. Most graphical objects will require the object be removed from all plots before the object can be deleted.

The WINDOWS Graphical Option

The WINDOWS graphical option is used to select those windows that a graphical object will appear in. This option is accessed using the *Windows* button on the right side of the Graphics Module option windows.

Windows Parameters

Display In: Each time a new window is created using the *Windows* pull down menu, an entry is added to the *Display In* list. You must choose one or more of these entries in order to display the graphical object in a window.

The CLIPPING Graphical Option

The CLIPPING graphical option is used to produce the effect of clipping planes on a graphical object. This option is accessed using the *Clipping* button appearing on the right side of the Environment Window of supporting Graphics Modules. The user can activate and define up to 4 clipping planes at a time using the “Clipping Parameters” appearing at the bottom of the Environment Window. To activate and define an individual clipping plane: Select a plane (i.e., Plane 0, Plane 1, Plane 2, or Plane 3), activate it using the *On* toggle switch, and adjust the rotation and translation sliders. The slider settings apply only to the Plane currently selected. The settings for individual planes are saved for the duration of a session. Additional clipping planes are created the same way and can be toggled On/Off to tailor 3D displays.

Clipping Parameters

On Off:	Toggle for activating the selected clipping plane, i.e., Plane 0.
Plane 0-3:	Select one of 4 independent clipping planes.
Rotate-X:	The <i>Rotate-X</i> option rotates the clipping planes around the current Y axis.
Rotate-Y:	The <i>Rotate-Y</i> option rotates the clipping planes around the current Z axis.
Translate-X:	The <i>Translate-X</i> option moves the clipping planes along the normal to the current X direction, as set by the rotate options.
Mirroring:	Some models support mirroring of data about an axis. This option turns mirroring of the data on.

The LIGHTING Graphical Option

The LIGHTING option is used to model the effect of light on a graphical object. The option names correspond to OpenGL graphics parameter names. This option is accessed using the *Lighting* button appearing on the right side of the Environment Window of supporting Graphics Modules. The user can activate and define up to 4 lighting sources at a time using the "Lighting Parameters" appearing at the bottom of the Environment Window. To activate and define an individual lighting source: Select a source (i.e., Light 0, Light 1, Light 2, or Light 3), activate it using the *On* toggle switch, and adjust the properties of the source, e.g., Position. The slider settings apply only to the light source currently selected. The settings for individual sources are saved for the duration of a session. Additional light sources are created the same way and can be toggled On/Off to tailor 3D displays.

Lighting Parameters

On off:	Toggle the lighting characteristics.
Light 0-3:	Select one of 4 independent lighting sources.
Specular:	Set the specular intensity of the light.
Diffuse:	Set the diffuse intensity of the light.
Ambient:	Set the ambient intensity of the light.
Position:	Set the position of the selected light source.
Red/Lat:	Specify the fraction of red or the latitude when position is selected.
Green/Long:	Specify the fraction of green or the longitude when position is selected.
Blue:	Specify the fraction of blue.

The MATERIAL Graphical Option

The MATERIAL option is used to modify the light reflection properties of graphical objects. The option names correspond to OpenGL graphics parameter names. This option is accessed using the *Material* button on the right side of the Graphics Module option windows.

Material Parameters

Shininess:	Set the shininess of the material.
Specular:	Set the specular color of the material.
Emission:	Set the emissive color of material.
Red/Shininess:	Specify the fraction of red or the shininess of the object when the shininess option is selected.
Green:	Specify the fraction of green.
Blue:	Specify the fraction of blue.

The TRANSFORM Graphical Option

The TRANSFORM graphical option is used to set limits on a data sample or to transform the data, e.g., take the log of the data. This option is accessed using the *Transform* button on the right side of the Graphics Module option windows used to display 2D and 3D data sets.

Transform Parameters

Data Transformation Parameters: Modify or constrain the data set.

- y(x):** Transform the original data using a specified function. For example, enter “log10(x)” to generate the log to base 10 of the data set or enter “log(x)” for log to base e of the data set. Also, enter “exp(x)” for e^x , “cos(x)” for cos(x), “sin(x)” for sin(x), “x^a” for x^a , and use the operators “+”, “-”, “/”, “*” for addition, subtraction, division, and multiplication, respectively.
- Data Limits:** Constrain the original data set to a specified range between *Min* and *Max*.
- Auto Range:** This resets the data range to the original minimum and maximum of the data set.

The TRANSFORMXY Graphical Option

The TRANSFORMXY graphical option is used to set limits on a line plot or to transform the data, e.g., take the log of the data. This option is accessed using the *Transform* button on the right side of the Graphics Module option windows used to display 1D data sets.

TransformXY Parameters

X (Y) Data Transformation Parameters: Modify or constrain the X or Y values of the data set.

x'(x) and y'(y): Transform the original data using a specified function. The $x'(x)$ function operates on the abscissa data; the $y'(y)$ operates on the ordinate data. For example, enter "log10(x)" after " $x'(x) =$ " to generate the log to base 10 of the abscissa. Likewise, enter "log10(x)" after " $y'(y) =$ " to generate the log to base 10 of the ordinate. Note that the expression parser always expects "x" as the dummy variable, so "log10(x)" is used even in the " $y'(y)$ " field. Refer to the TRANSFORM Graphical Option section for a list of available functions.

Data Limits: Constrain the original data set to a specified range between *Min* and *Max* of either X or Y data.

Auto Range: This resets the data range to the original minimum and maximum of the data set.

The TRANSPARENCY Graphical Option

The TRANSPARENCY graphical option is used to produce the effect of transparency on a graphical object. This option is accessed using the *Transp.* button on the right side of the Graphics Module option windows.

Transparency Parameters

Alpha Value: The transparency option controls the fraction of light transmitted through the object. An alpha value of 1.0 corresponds to complete opacity and a value of 0.0 corresponds to complete transmission, i.e., the object is invisible.

The 1D OPTIONS Graphical Option

The 1D OPTIONS graphical option is used to set parameters of a line plot. This option is accessed using the *Options* button on the right side of the Graphics Module option windows.

1D Option Parameters

Draw:	This options menu allows the user to choose how the line plot should be rendered. The line may be rendered as <i>Lines</i> , i.e., a series of connected points, or as <i>Points</i> , i.e., discrete points.
Y-Axis:	This option menu allows the user to choose where the y-axis is drawn. Choices are <i>Off</i> for no axis to be drawn, <i>Left</i> for the y-axis to be drawn to the left of the plot, and <i>Right</i> for it to be drawn to the right of the plot.
X-Axis:	This option menu allows the user to choose whether the x-axis should be drawn for this line. Choices are <i>Off</i> or <i>On</i> .
SwapXY:	This option menu allows the user to choose whether the x-axis is horizontal and y-axis vertical, or vice versus. Choices are <i>Y vs. X</i> for x-horizontal and y-vertical or <i>X vs. Y</i> for y-horizontal and x-vertical.
Choose Color:	This allows the user to set the line to an arbitrary color.
Title:	Places the specified title at the top of the plot.
XLabel:	Places the specified label as the x-axis label. An empty value causes a default to be generated.
YLabel:	Places the specified label as the y-axis label. An empty value causes a default to be generated.
XFormat:	Determines the format of the x-tic marks. "C"-like format statements are the accepted format, e.g., "%5.2f" will label the x-tics using floating point numbers with two decimal places. In addition, the key "%0D" will write time formatted as HH:MM:SS.SS. The key "%1D" will write time formatted as DDD HH:MM, where DDD=day of year. The key "%2D" will write time formatted as MM/DD HH:MM. Using these keys on a non-time axis is undefined. An empty value generates a default.
YFormat:	Determines the format of the y-tic marks. "C"-like format statements are the accepted format. For example, "%5.2f" will label the y-tics using floating point numbers with two decimal places. In addition, the key "%0D" will write time formatted as HH:MM:SS.SS. The key "%1D" will write time formatted as DDD HH:MM, where DDD=day of year. The key "%2D" will write time formatted as MM/DD HH:MM. Using these keys on a non-time axis is undefined. An empty value generates a default.
XTics:	Determines the number of x-tic marks. An empty value causes a default to be generated.
YTics:	Determines the number of y-tic marks. An empty value causes a default to be generated.

The MARKER Graphical Option

The MARKER option is used to set the size and resolution of a sphere representing the satellite. This option is accessed using the *Marker* button on the right side of the Graphics Module option windows.

Marker Parameters

Radius:	Radial dimension of the satellite sphere (radius of Earth = 1).	-
Resolution:	The number of angle bins (both polar and azimuthal) used to build the satellite sphere.	-

Worksheet Modules

Worksheet modules provide auxiliary tools that are often helpful in AF-GEOSpace calculations. The worksheet modules are accessed through the worksheet module manager which becomes visible when the *Worksheet* button under the Environment's Modules pulldown menu is activated. The worksheet module manager consists of two lists - *Available Worksheet Modules* and *Active Worksheet Modules*. *Available Worksheet Modules* are the modules which are currently supported by AF-GEOSpace. *Active Worksheet Modules* are modules which have been created and used by the AF-GEOSpace user during the current session.

When initially accessed, the worksheet module manager will show a list of worksheet modules under *Available Worksheet Modules*. Since no worksheet modules have yet been created, the *Active Worksheet Modules* list will be empty.

Currently, the following worksheet modules are supported by AF-GEOSpace:

- **CALENDAR:** A calendar showing month and day, day of year, and modified Julian day.
- **COORD_TRANSFORM:** Transform between coordinate frames.

Running Worksheet Modules

To run a *Worksheet*, click the mouse on the desired choice under the *Available Worksheet Modules*. For example, to create a new version of the CALENDAR module, click the mouse on *CAL-NDAR* in the *Available Worksheet Modules* list. Choosing a worksheet will do two things: first, the choice is added to the *Active Worksheet Modules* list; second, the options associated with the chosen worksheet will appear below the worksheet manager windows. In general, each worksheet will have a different Environment Window representing the inputs specific to the worksheet.

The bottom section of the worksheet window is the same for all worksheets. It consists of a status window and buttons for running and deleting the worksheet, a button to access the grid tool, and a button to allow the worksheet data to be saved to a file.

- **Model Status:** The *Model Status* box provides a brief informational message regarding the current state of the worksheet. Upon creation, the status will be "MODEL INITIALIZED". If the worksheet is up-to-date and ready for use by other modules, the message will indicate "MODEL IS READY AND UP TO DATE". If parameters have been changed since last running the worksheet, the status box will indicate "PARAMETERS MAY HAVE CHANGED". Other informational messages may also be displayed depending on the specific worksheet. A scroll feature is provided for reading longer messages.
- **Run Model:** Is not currently used by any worksheets.
- **Delete Model:** If the worksheet is no longer needed, it may be deleted by selecting the *Delete Model* button.
- **Grid Tool:** Is not currently used by any worksheets.
- **Save To File:** Is not currently used by any worksheets.

The CALENDAR Worksheet Module

Model Name: Calendar
Version: 1996
Developer: Rodger Biasca, Boston College
References: NONE

CALENDAR Overview

The CALENDAR Worksheets module displays a calendar showing a specified month. The dates include day of year and modified Julian day.

CALENDAR Inputs

The CALENDAR worksheet module requires the following inputs:

Year/Month: The year and month of the calendar to display.

CALENDAR Outputs

CALENDAR displays the specified month of the specified year.

The COORD_TRANSFORM Worksheet Module

Model Name: COORD_TRANSFORM
Version: 1996
Developer: Boston College and Air Force Research Laboratory
References: Bhavnani, K.H., and R.P. Vancour, Coordinate Systems For Space and Geophysical Applications, *PL-TR-91-2296*, Phillips Laboratory, Hanscom AFB, MA (1991), ADA 247550
Russell, C.T., Geophysical Coordinate Systems, *Cosmic Electrodynamics*, 2, 184-196 (1971)

COORD_TRANSFORM Overview

The COORD_TRANSFORM worksheet module allows the user to perform a coordinate transform of a single point.

COORD_TRANSFORM Inputs

The COORD_TRANSFORM worksheet module requires the following inputs:

Year/Day/UT: The year, day of year, and UT at which to perform the conversion.

Input Geometry: The geometry in which to specify the input point. Choices are:

- Cartesian: Generate a grid in cartesian geometry.
- Cylindrical: Generate a grid in cylindrical geometry.
- Spherical: Generate a grid in spherical geometry.

Input Coordinates: Specifies the coordinate system of the input point. The choices are:

- GEOC: Geocentric coordinate system: The Z axis is aligned with the north rotational pole, the X axis pierces the Greenwich Meridian on the equator (0 deg Long, 0 deg Lat), and the Y axis completes the right handed system.
- GSM: Geocentric solar magnetospheric coordinate system: The X axis points to the Sun. The Z axis is perpendicular to X and lies in the plane containing the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.
- SM: Solar magnetic coordinate system: The X axis is perpendicular to Z and lies in the plane containing the Z axis and the Earth-Sun line. The Z axis is coincident with the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.
- GEI: Geocentric equatorial inertial coordinate system: The Z axis is the same as for the geocentric coordinate system (GEOC). The X axis points in the direction of the first

point of Aries (vernal equinox). The Y axis completes the right handed system. The angle between the X axis and Greenwich Meridian is set by the UT from the animation window.

- Input C0, C1, C2: The three coordinate components of the input points, specified in the units given by the labels.
- Output Geometry: The geometry in which to specify the output point. Choices are
 - Cartesian: Generate a grid in cartesian geometry.
 - Cylindrical: Generate a grid in cylindrical geometry.
 - Spherical: Generate a grid in spherical geometry.
- Output Coordinates: Specifies the coordinate system of the output point. The choices are:
 - GEOC: Geocentric coordinate system: The Z axis is aligned with the north rotational pole, the X axis pierces the Greenwich Meridian on the equator (0 deg Long, 0 deg Lat), and the Y axis completes the right handed system.
 - GSM: Geocentric solar magnetospheric coordinate system: The X axis points to the Sun. The Z axis is perpendicular to X and lies in the plane containing the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.
 - SM: Solar magnetic coordinate system: The X axis is perpendicular to Z and lies in the plane the Z axis and the Earth-Sun line. The Z axis is coincident with the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.
 - GEI: Geocentric equatorial inertial coordinate system: The Z axis is the same as for the geocentric coordinate system (*GEOC*). The X axis is aligned along the vernal equinox. The Y axis completes the right handed system. The angle between the vernal equinox and the Greenwich Meridian is set by the current UT from the animation window.

COORD_TRANSFORM Outputs

COORD_TRANSFORM displays the three components of the output point in the new units.

Plotting Windows

This section describes the plotting window options available for 1D, 2D, and 3D graphics objects. In addition, the options available for animation are described.

Currently AF-GEOSpace supports the following plotting window options,

- **Plot 1D Windows:** Create windows to plot 1D graphics objects.
- **Plot 2D Windows:** Create windows to plot 2D and certain 1D graphics objects.
- **Plot 3D Windows:** Create windows to plot 3D and certain 2D and 1D graphics objects.
- **Animation:** Animate dynamic graphics objects, i.e., SATELLITE, in available windows.

Plot 1D Windows

The *Create 1D plot* button in the *Windows* pulldown menu opens a new 1D window for plotting. An entry is automatically made into the windows option *Display In* widget for all available graphical objects. Selecting this entry displays the graphical object in the 1D window.

A plot 1D window has three pulldown menus. These are described below.

- | | |
|-----------------------|---|
| Admin: | The <i>Admin</i> menu provides for the following administrative functions. |
| Delete: | This button deletes the window (only if all the graphical objects have been removed from the window). |
| Print: | Print the window to a file or printer in RGB, postscript, or GIF image format. |
| Options: | The <i>Options</i> menu provides for the following window options. |
| Set Background Color: | Change the background to an arbitrary color. |
| Set Font: | Change the font for text in the window. |
| Captions: | The <i>Captions</i> menu provides for the following window options. |
| Show Captions: | Toggle the captions. |
| Caption Text: | Type in up to three captions at selected window positions. The window area is defined by x and y coordinates in the range [0, 1]. |
| Caption Color: | Set the caption color. |
| Set Font: | Set the caption font. |

Plot 2D Windows

The *Create 2D plot* button in the *Windows* pulldown menu opens a new 2D window for plotting. An entry is automatically made into the windows option *Display In* widget for all available graphical objects. Selecting this entry displays the graphical object in the 2D window.

The plot 2D window has four pulldown menus plus a set of mouse controls as described below.

Admin:	The <i>Admin</i> menu provides for the following administrative and display functions.
Delete:	This button deletes the window (only if all the graphical objects have been removed from the window).
Show_view:	This button brings up a sub-menu of viewing options which include the following, <ul style="list-style-type: none">Latitude: Controls the viewer's look angle with respect to latitude.Longitude: Controls the viewer's look angle with respect to longitude.Twist: Rotates the view around the current line of sight.Scale: Multiplies the object x, y, and z coordinates by a common factor producing a central expansion or contraction. For large expansions, the objects will eventually hit a clipping plane.Zoom: Scales the window by moving the clipping planes.Translate X: Translates the object along the X axis.Translate Y: Translates the object along the Y axis.Translate Z: Translates the object along the Z axis.
Print:	Print the window to either a file or printer using RGB image or postscript format.

Note: The maximum of the *Zoom*, *Scale*, and *Translate* sliders can be halved or doubled by touching the cursor on the label and pressing mouse button 1 or 3, respectively. The minimum of the *Zoom*, *Scale*, and *Translate* sliders can be similarly halved or doubled by pressing both the *Ctrl* key and mouse button 1 or 3, respectively. There are also reset buttons for all options.

Options:	The <i>Options</i> menu provides for the following window options. <ul style="list-style-type: none">Set Background Color: Change the background to an arbitrary color.Set Label Color: Change the color bar labelling to an arbitrary color.Set Font: Change the font with which text is drawn in the window.
----------	--

- Show Color Bar: Toggle the color Bar.
- Show Hints: Toggle the control hints given at the bottom of the plot.
- Projections: The *Projections* menu allows the image to be displayed in a variety of different projections. The projection choices are:
- ENH: East-North-Height. Equi-spaced latitude and longitude increments. The center of the plot is latitude=0, longitude=0.
 - ENH-WRAP: East-North-Height wrapped. Equi-spaced latitude and longitude increments. The plot wraps around so the user may select the center latitude and longitude of the plot.
 - Mollweide: Project in a Mollweide projection.
 - Parabolic: Project in a Parabolic projection.
 - Sinusoidal: Project in a Sinusoidal projection.
 - Polar Orthographic: Project in a polar orthographic projection.
 - Polar Azimuthal: Project in a polar azimuthal projection.
- Captions: The *Captions* menu provides for the following window options.
- Show Captions: Toggle the captions.
 - Caption Text: Enter up to three captions at selected window positions. The window area is defined by x and y coordinates in the range [0, 1].
 - Caption Color: Set the caption color.
 - Set Font: Set the caption font.
- Mouse controls: Mouse controls are provided to facilitate manipulation of the window view. The control hints at the bottom of the window give the available options.
- Button 1: Allows one to probe the latitude and longitude at the cursor.
 - Button 2: Allows one to zoom the view.
 - Button 3: Allows one to translate the view in the Y or Z directions.
- Note:** Any zoom or translate changes made with the mouse will be reflected in the *Show_view* menu.

Plot 3D Windows

The *Create 3D plot* button in the *Windows* pulldown menu opens a new 3D window for plotting. An entry is automatically made into the windows option *Display In* widget for all available graphical objects. Selecting this entry displays the graphical object in the 3D window.

A plot 3D window has four pulldown menus plus a set of mouse controls as described below.

Admin:	The <i>Admin</i> menu provides for the following administrative and display functions.
Delete:	This button deletes the window (only if all the graphical objects have been removed from the window).
Show_view:	This button brings up a sub-menu of viewing options which include the following, <ul style="list-style-type: none">Latitude: Controls the viewer's look angle with respect to latitude.Longitude: Controls the viewer's look angle with respect to longitude.Twist: Rotates the view around the current line of sight.Scale: Multiplies the object x, y and z coordinates by a common factor producing a central expansion or contraction. For large expansions, the objects will eventually hit a clipping plane.Zoom: Scales the window by moving the clipping planes.Translate X: Translates the object along the X axis.Translate Y: Translates the object along the Y axis.Translate Z: Translates the object along the Z axis.
Print:	Print the window to either a file or printer in RGB, postscript, or GIF image format.

Note: The maximum of the *Zoom*, *Scale*, and *Translate* sliders can be halved or doubled by touching the cursor on the label and pressing mouse button 1 or 3, respectively. The minimum of the *Zoom*, *Scale*, and *Translate* sliders can be similarly halved or doubled by pressing both the *Ctrl* key and mouse button 1 or 3, respectively. There are also reset buttons for all options.

Options:	The <i>Options</i> menu provides for the following window options.
Set Background Color:	Change the background to an arbitrary color.
Set Label Color:	Change the color bar labelling to an arbitrary color.
Set Font:	Change the font with which text is drawn in the window.

Show Color Bar: Toggle the color Bar.

Show Hints: Toggle the control hints given at the bottom of the plot.

Perspective View: Changes the orthographic projection to a perspective projection. This shows foreshortening: the farther away an object is, the smaller it appears.

Data Probe Mouse: Toggles the probe option for looking at selected data values.

Button 1: Select the data set.

Button 2: Display coordinates (Rad, Lat, Lon) and data value.

Button 3: Display coordinates (X, Y, Z) and data value.

Frame: Sets the coordinate reference frame used if the plot is animated. The choices are,

GEOC: Geocentric coordinate system: The Z axis is aligned with the north rotational pole, the X axis pierces the Greenwich Meridian on the equator (0 deg Long, 0 deg Lat), and the Y axis completes the right handed system.

GEI: Geocentric equatorial inertial coordinate system: The Z axis is the same as for the geocentric coordinate system (*GEOC*). The X axis points in the direction of the first point of Aries (vernal equinox). The Y axis completes the right handed system. The angle between the X axis and Greenwich Meridian is set by the UT from the animation window.

GSM: Geocentric solar magnetospheric coordinate system: The X axis points to the Sun. The Z axis is perpendicular to X and lies in the plane containing the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.

SM: Solar magnetic coordinate system: The X axis is perpendicular to Z and lies in the plane the Z axis and the Earth-Sun line. The Z axis is coincident with the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.

Solar: A translated and scaled GSM frame which allows both the Earth and Sun to be shown.

Captions: The *Captions* menu provides for the following window options,

Show Captions: Toggle the captions.

- Caption Text: Enter up to three captions at selected window positions. The window area is defined by x and y coordinates in the range [0, 1].
- Caption Color: Set the caption color.
- Set Font: Set the caption font.
- Mouse controls: Mouse controls are provided to facilitate manipulation of the window view. The control hints at the bottom of the window give the available options.
- Button 1: Allows one to rotate the displayed objects.
- Button 2: Allows one to expand or contract the view.
- Button 3: Allows one to translate the view in the X, Y, or Z directions.

Note: Any changes made with the mouse will be reflected in the *Show_view* menu.

Animation

The *Animation* button in the *Windows* pulldown menu brings up an Animation Window for controlling animation effects. In the current version of AF-GEOSpace (Version 1.4), the only graphics objects with time dependence are SATELLITEs. Thus it is the attributes of the SATELLITE Data Sets (start time, stop time, time step) that control the animation. The Animation Window entries are described below.

Start/Continue:	This starts the animation stepper at the time indicated by the <i>Time</i> slider.
Pause:	This stops the stepper at the current time.
Exit:	Exits the animation module.
Time:	Slider to set the current step time.
Step:	Arrows to step the time forward or backward.
Find range:	Set the range of the step times. For a single track, this sets the start and stop times to the minimum and maximum times for the orbit. For multiple tracks, the overall minimum and maximum time for all the orbits is used.
T_start:	Sets the start time for the stepper in days.
T_stop:	Sets the stop time for the stepper in days.
DT_(sec):	Sets the time increment for the stepper in seconds.

Currently the orbit year is ignored in animation calculations. The value shown for the year under the animation time slider and at the bottom of the plot windows during stepping is the year value from the global parameters, thus *Animation* will not work for orbits that cross year boundaries.

Note: The animation algorithm is set to give a reasonable zeroth order depiction of the dynamics. However, one must be careful of the chosen frame in which to perform the animation (see the Plot 3D Window section of the documentation). For example, in the inertial frame, all graphical objects frozen in form at the time they were created are assumed to rigidly rotate with the Earth. This will be a fairly good approximation for those data that tend to follow the Earth, e.g., the radiation belts. It will be a poor approximation for some cases, e.g., the magnetic field lines for magnetic field models with an external field component.

Miscellaneous Topics

This section describes the following options available in the Science and Applications Modules,

- **Messaging System:** Allows users to create, save, and view text messages.
- **Grid Tool:** Specify the grid and binning resolution for 3D and 2D Data Sets created by Science and certain Applications Modules.
- **Save to File:** Enables data sets to be saved to files of various formats.
- **Environment Variables:** Describes the set of AF-GEOSpace shell environment variables.
- **Xdefault Variables:** Describes the set of AF-GEOSpace Science and Application Module variables that can be set through the .Xdefaults file.

Messaging System

AF-GEOSpace provides a messaging system to relay messages to other AF-GEOSpace users or save information for future AF-GEOSpace sessions. The messaging system is invoked by activating the *Messages* button on the AF-GEOSpace welcome window.

Activating the *Messages* button opens a *Messages* window. The window contains areas for control buttons, a message, and a reply. The functionality of each option is described below:

Control buttons are included to create, save, delete, and move through saved messages. Specifically, the buttons are

- Save Messages:** Write the current set of messages to the message file and thus save the messages between AF-GEOSpace sessions. After adding or changing messages, this button should always be invoked to assure that the modified messages are saved.
- Cancel Changes:** Discard all changes made to messages and revert to the previously saved message file.
- Delete Message:** Delete the current message.
- New Message:** Create a new, empty message.
- Next Message:** Move forward in the message list.
- Prev. Message:** Move backward in the message list.
- Index:** Open a window showing the reference number and subject of each message. A message can be accessed by double clicking the subject in the index popup box.

Text fields are provided for the following:

- Date:** The date the message was created.
- Ref Number:** A reference number for the message.
- Subject:** A short subject header describing the message contents.
- Message:** The message to be relayed to the AF-GEOSpace developers or other users.
- Reply:** The reply to the message from the AF-GEOSpace developers or other users.

The Grid Tool

The *Grid Tool* option allows one to specify the type and resolution of the grid used by science and application modules. If the default grid settings are desired then the *Grid Tool* need not be used. After selecting from the *Grid Tool* options described below, clicking the *Apply* button or closing the Grid Setup Window will generate the grid. The *Cancel* button should be used to exit the Grid Setup Window if no grid changes are desired.

Note: Grids based on the time dependent coordinate systems GSM, SM, and GEI must be regenerated whenever the time at the top of the Environment Window is changed.

Spacing: Specifies the manner in which the grid spacing is calculated. Choices are:

Linear: Equally spaced grid points along coordinate direction are generated.

N-S Symm: Symmetrically spaced grid points along North-South direction are generated and no grid points need exist in the equatorial regions (useful for auroral calculations). For example, with a spherical *Geometry* setting the grid points are evenly spaced between the absolute value of the specified minimum and maximum latitudes in both the Southern and Northern hemisphere, e.g., for a minimum latitude of 50° and a maximum latitude of 90°, grid points will be evenly spaced between 50° and 90° North latitude and 50° and 90° South latitude. No grid points will exist between 50° South and 50° North latitude.

Geometry: Specifies the geometry of the grid. Choices are:

Cartesian: generate a grid in cartesian geometry.

Cylindrical: generate a grid in cylindrical geometry.

Spherical: generate a grid in spherical geometry.

System: Specifies the coordinate system of the grid. The choices are:

GEOC: Geocentric coordinate system: The Z axis is aligned with the north rotational pole, the X axis pierces the Greenwich Meridian on the equator (0 deg Long, 0 deg Lat), and the Y axis is minus the cross-product of X and Z.

GSM: Geocentric solar magnetospheric coordinate system: The X axis points to the Sun. The Z axis is perpendicular to X and lies in the plane containing the magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.

SM: Solar magnetic coordinate system: The X axis is perpendicular to Z and lies in the plane containing the Z axis and the Earth-Sun line. The Z axis is coincident with the

magnetic dipole axis. The Y axis completes the right handed system and is positive towards dusk.

GEI: Geocentric equatorial inertial coordinate system: The Z axis is the same as for the geocentric coordinate system (*GEOC*). The X axis points in the direction of the first point of Aries (vernal equinox). The Y axis completes the right handed system. The angle between the X axis and Greenwich Meridian is set by the UT from the Animation Window.

Set (?, ?, ?): For each of the three coordinates, the user must input the grid sizes. Each coordinate contains a selection list for setting combinations of three of the four variables needed to specify this coordinate. The variables are,

Delta: the interval between nodes.

NPoints: the total number of nodes.

Min: the minimum coordinate value.

Max: the maximum coordinate value.

Note: The coordinate labels *Radius*, etc., will change to correspond to the different types of systems chosen. One must close the Grid Setup window in order to activate any changes.

Saving Models

The *Save To File* option enables one to write out data and parameters describing a Science or Application module.

Selecting the *Save To File* option button brings up an Output File Window with entries of the following type:

Select Output Type: The format in which to save the requested data.

ASCII: Selects an ASCII file format.

BUFR: Selects a BUFR file format.

netCDF: Selects a netCDF file format.

Select Variables to Save: A selection list of variables relevant to the case is given:

Globals: The settings of the global variables for this case.

Inputs: The local input variables for the case.

Coords: The coordinate system for the case.

Data: The data output for the case. The data output can consist of a list of many variables.

Output File: Set the name of the output file.

Save: Selecting the *Save* button writes the data to the "Output File" named.

Environment Variables

A large number of environment variables may be set to override AF-GEOSpace's standard directory search paths and some other defaults. This section lists available environment variables and their use. Under csh, the environment variables may be set by a command of the form

```
setenv VARIABLE value
```

where *VARIABLE* is the name of the environment variable and *value* is the desired result.

PLGS_BACKGROUND_(RED, GREEN, BLUE)

the default RGB values for the color of the drawing window background. Each is a floating point value between 0. and 1.0

(default: 0.0)

PLGS_BCAPEX_DATADIR

the directory containing example datasets used in the BCAPEX data module

(default: \$(PLGS_MODELS)/MODELS/data/BCAPEX)

PLGS_BCDMSP_DATADIR

the directory containing the data files used by the HEEM module

(default: /disk2/scr2nash/heproj/case)

PLGS_BCSPECTRA_DATADIR

the directory containing the data files used by the DMSP-SPECTRA module

(default: /disk2/scr2nash/holeman/dmsp/rdata)

PLGS_BCONV0_PROG

the executable BFCNV0 program used by the radiation belt science modules to convert from geographic to BL coordinates for dipole and IGRF magnetic field models

(default: \$(PLGS_MODELS)/MODELS/src/BCONV0/bfconv0)

PLGS_BCONV1_PROG

the executable GEOGSM program to convert from geographic to GSM coordinates used to generate a GSM grids

(default: \$(PLGS_MODELS)/MODELS/src/BCONV1/geogsm)

PLGS_BFGEOS_PROG

the executable BFGEOS program used by the B-field application

(default: \$(PLGS_MODELS)/MODELS/src/BFGEOS/bfgeos)

PLGS_BUFR_DATADIR

the directory containing tables needed by the BUFR output

(default: \$(PLGS_MODELS)/MODELS/data/BUFR)

PLGS_CELE_FLUXDATA_PROG

the executable FLUXDATA program used by the CRRESELE application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESELE/fluxdata)

PLGS_CELE_LOKANGLE_PROG

the executable LOKANGLE program used by the CRRESELE application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESELE/lokangle)

PLGS_CELE_MAGMODEL_PROG

the executable MAGMODEL program used by the CRRESELE application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESELE/magmodel)

PLGS_CELE_TIMEBINS_PROG

the executable TIMEBINS program used by the CRRESELE application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESELE/timebins)

PLGS_CPRO_FLUXDATA_PROG

the executable FLUXDATA program used by the CRRESPRO application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESPRO/fluxdata)

PLGS_CPRO_LOKANGLE_PROG

the executable LOKANGLE program used by the CRRESPRO application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESPRO/lokangle)

PLGS_CPRO_MAGMODEL_PROG

the executable MAGMODEL program used by the CRRESPRO application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESPRO/magmodel)

PLGS_CPRO_TIMEBINS_PROG

the executable TIMEBINS program used by the CRRESPRO application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESPRO/timebins)

PLGS_CRAD_DOSEDATA_PROG

the executable DOSEDATA program used by the CRRESRAD application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESRAD/dosedata)

PLGS_CRAD_LOKANGLE_PROG

the executable LOKANGLE program used by the CRRESRAD application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESRAD/lokangle)

PLGS_CRAD_MAGMODEL_PROG

the executable MAGMODEL program used by the CRRESRAD application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESRAD/magmodel)

PLGS_CRAD_TIMEBINS_PROG

the executable TIMEBINS program used by the CRRESRAD application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESRAD/timebins)

PLGS_CRRESDOSE_DATADIR

the directory containing data needed by the model CRRESDOSE

(default: \$(PLGS_MODELS)/MODELS/data/CRRESDOSE)

PLGS_CRRESELE_DATADIR

the directory containing data needed by the model CRRESELE

(default: \$(PLGS_MODELS)/MODELS/data/CRRESELE)

PLGS_CRRESPRO_DATADIR

the directory containing data needed by the model CRRESPRO

(default: \$(PLGS_MODELS)/MODELS/data/CRRESPRO)

PLGS_EARTH_DATADIR

the directory containing data needed by the graphical object EARTH

(default: \$(PLGS_MODELS)/MODELS/data/EARTH)

PLGS_EARTH_PROG

the executable READER program used by the EARTH graphical object to read the content database

(default: \$(PLGS_MODELS)/MODELS/src/EARTH/reader)

PLGS_EPHEMERIS_DATADIR

the directory containing data needed by the ORBIT propagators

(default: \$(PLGS_MODELS)/MODELS/data/EPHEMERIS)

PLGS_EQEDGE_PROG

the executable EQEDGE program used by the AURORA science module to calculate the equatorward edge

(default: \$(PLGS_MODELS)/MODELS/src/EQEDGE/eqedge)

PLGS_EXEC

the directory containing the AF-GEOSpace executable. If this is not set, the code determines the location from the command line (default ~geospace/bin)

PLGS_IAPIM_DATADIR

the directory containing data needed by the model AURORA

(default: \$(PLGS_MODELS)/MODELS/data/IAPIM)

PLGS_KP_DATADIR

the directory containing the historic global parameter data

(default: \$(PLGS_MODELS)/MODELS/data/KP)

PLGS_LABEL_FONT

the font used for labeling on the plots

(default: 7x14)

PLGS_LABEL_(RED, GREEN, BLUE)

the default RGB values for the label font color. Each is a floating point value between 0. and 1.0

(default: 1.0)

PLGS_LOKANGLE_PROG

the executable LOKANGLE program used by the orbit application

(default: \$(PLGS_MODELS)/MODELS/src/UNIX_CRRESBASE/lokangle)

PLGS_MODELS

the directory containing the top directory MODELS. If this is not set, the code will search . , .. and ../. for the directory

(default: ~geospace)

PLGS_NASADOSE_DATADIR

the directory containing data needed by the model NASADOSE

(default: \$(PLGS_MODELS)/MODELS/data/NASADOSE)

PLGS_NASAELE_DATADIR

the directory containing data needed by the model NASAELE

(default: \$(PLGS_MODELS)/MODELS/data/NASAELE1.2)

PLGS_NASAPRO_DATADIR

the directory containing data needed by the model NASAPRO

(default: \$(PLGS_MODELS)/MODELS/data/NASAPRO1.2)

PLGS_PIM_DATADIR

the directory containing data needed by the model PIM and IMAS application to run PIM

(default: \$(PLGS_MODELS)/MODELS/data/PIM)

PLGS_PIM_PROG

the executable PIM program

(default: \$(PLGS_MODELS)/MODELS/src/PIM/pim/bin/pim)

PLGS_RADEX_DATADIR

the directory containing examples datasets used in the RADEX data module

(default: \$(PLGS_MODELS)/MODELS/data/BENCH)

PLGS_RADEX_PIM_PROG

the executable IMAS program

(default: \$(PLGS_MODELS)/MODELS/src/RADEX_PIM/pud)

PLGS_RADEX_PIM_SRC

the directory containing the IMAS code

(default: \$(PLGS_MODELS)/MODELS/src/RADEX_PIM)

PLGS_SGP4_PROG

the executable SGP4 program used by the orbit application

(default: \$(PLGS_MODELS)/MODELS/src/SGP4/sgp4)

PLGS_WBMOD_PROG

the executable WBMOD program

(default: \$(PLGS_MODELS)/MODELS/src/WBMOD/src/wbmod)

Xdefault Variables

A large number of defaults for the science modules and applications can be set through the .Xdefaults file. This section describes the variables and their use. The application name is AF-GEOSpace, hence a line of the form

AF-GEOSpace**variable*: *value*

where *variable* is the variable name to be set and *value* is the desired result can be used to override the internal model defaults.

Several variables are supported across most models. These variables have the form xxxVariable where xxx=model name. For example, the X-Dimension of the aurora model has the name auroraGridXDim. The specific variable names and their meaning are:

xxxGridXDim

the default dimension of the first grid coordinate.

xxxGridXMin

the minimum value of the first grid coordinate

xxxGridXMax

the maximum value of the first grid coordinate

xxxGridYDim

the default dimension of the second grid coordinate.

xxxGridYMin

the minimum value of the second grid coordinate

xxxGridYMax

the maximum value of the second grid coordinate

xxxGridZDim

the default dimension of the third grid coordinate.

xxxGridZMin

the minimum value of the third grid coordinate

xxxGridZMax

the maximum value of the third grid coordinate

xxxOutputFile

the default output file for the model

The following variables affect the default global parameters,

globalDefaultKp

the Kp displayed in the global parameters (default: -1)

globalDefaultSSN

the sun spot number displayed in the global parameters (default: -1)

globalDefaultF10

the F10.7 value displayed in the global parameters (default: -1)

globalDefaultAp

the Ap value displayed in the global parameters (default: -1)

Note: The default for the year, day and UT global parameters are set by the system clock.

The AURORA model uses auroraGridXDim (default: 1), auroraGridXMin (default: 1.0173 Re = 110 km), auroraGridXMax (default: 1.0173 Re = 110 km), auroraGridYDim (default: 50), auroraGridYMin (default: 40.0), auroraGridYMax (default: 89.9), auroraGridZDim (default: 48), auroraGridZMin (default: -180), auroraGridZMax (default: 180), and auroraOutputFile (default: aurora.out). In addition, the following variables affect the model defaults:

auroraIntField

the default internal field used by the AURORA science module. Choices are DIPOLE_INT_FIELD, IGRF_INT_FIELD or FAST_IGRF_INT_FIELD. (default: DIPOLE_INT_FIELD)

auroraExtField

the default external field used by the AURORA science module. Choices are NO_EXT_FIELD, HILMER_VOIGT_EXT_FIELD, OLSON_PFITZER_EXT_FIELD, TSYGANENKO_1989_EXT_FIELD, or TSYGANENKO_1987_EXT_FIELD. (default: NO_EXT_FIELD)

auroraHVMode

the default mode used by the AURORA science module with the Hilmer-Voigt external field. Choices are KP_ONLY_HV_MODE, DST_EQEDGE_STANDOFF_HV_MODE, or VACUUM_HV_MODE. (default: KP_ONLY_HV_MODE)

auroraDstModel

the default value of the discrete Dst model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = -600; 1 = -500.0; 2 = -400; 3 = -300; 4 = -200; 5 = -150; 6 = -100; 7 = -50; 8 = 0; 9 = 50; (default: 5)

auroraEqEdgeModel

the default value of the discrete equatorward edge model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = 34.38, 1 = 43.93, 2 = 49.47, 3 = 53.20, 4 = 55.89, 5 = 57.96, 6 = 59.60, 7 = 60.95, 8 = 62.06, 9 = 63.02, 10 = 63.99, 11 = 65.01, 12 = 65.91, 13 = 66.72, 14 = 67.45, 15 = 68.12, 16 = 68.73, 17 = 69.30; (default: 8)

auroraStandoffModel

the default value of the discrete standoff distance model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = 4.0; 1 = 6.0; 2 = 8.0; 3 = 10.0; 4 = 12.0; 5 = 14.0; (default: 3)

auroraStandoffValue

the default value of the standoff distance when using Hilmer-Voigt in Vacuum Config mode.
Use $4 < \text{Standoff} < 14$. (default: 10.0)

auroraT89Mode

the default mode for the Tsyganenko '89 model. Choices are KP_ONLY_T89_MODE or AE_ONLY_T89_MODE; (default: KP_ONLY_T89_MODE)

auroraAeModel

the default value of the discrete Ae range when using the Tsyganenko '89 model in Ae Only mode. Use $0 = 0 < Ae < 50$; $1 = 50 < Ae < 100$; $2 = 100 < Ae < 150$; $3 = 150 < Ae < 250$; $4 = 250 < Ae < 400$; $5 = 400 < Ae$; (default: 0)

auroraMapEqEdge

boolean value: true if the equatorward edge should be calculated (default: false)

auroraMapNorth

boolean value: true if the equatorward edge should be mapped from the northern hemisphere
(default: true)

auroraMapSouth

boolean value: true if the equatorward edge should be mapped from the southern hemisphere
(default: false)

auroraCalcGridData

boolean value: true if the aurora values should be calculated on the grid (default: true)

auroraEEMode

the default mode in which the equatorward edge will be specified. Choices are EQEDGE_USE_GLOBAL_KP or EQEDGE_CALC_EFF_KP.
(default: EQEDGE_USE_GLOBAL_KP)

auroraEEPoints

the default number of points to use in the equatorward edge calculation (default: 24)

auroraEEMLT

the default MLT to use when specifying an observed equatorward edge (default: 0.0)

auroraEEMLAT:

the default magnetic latitude to use when specifying an observed equatorward edge
(default: 70.0)

The CRRESELE model uses crreseleGridXDim (default: 60), crreseleGridXMin (default: 1.1), crreseleGridXMax (default: 7.0), crreseleGridYDim (default: 60), crreseleGridYMin (default: -68.0), crreseleGridYMax (default: 68.0), crreseleGridZDim (default: 60), crreseleGridZMin (default: -180), crreseleGridZMax (default: 180), and crreseleOutputFile (default: crresele.out). In addition, the following variables affect the model defaults:

crreseleBModel

the default value determining which B-Field mapping is to be used. Choices are CRRESELE_BFIELD_DIPOLE, CRRESELE_BFIELD_TILTDIPOLE, CRRESELE_BFIELD_TILTOFFSETDIPOLE, CRRESELE_BFIELD_IGRF, or CRRESELE_BFIELD_IGRFOP (default: CRRESELE_BFIELD_IGRFOP)

crreseleEnergyChannel

the default value determining which energy channel is initially selected. Use 1 = 0.65, 2 = 0.95, 3 = 1.60, 4 = 2.00, 5 = 2.35, 6 = 2.75, 7 = 3.15, 8 = 3.75, 9 = 4.55, 10 = 5.75; (default: 1)

crreseleApModel

the default value determining which Ap range is initially selected. Use 1 = $5.0 < A_p < 7.5$; 2 = $7.5 < A_p < 10.0$; 3 = $10.0 < A_p < 15.0$; 4 = $15.0 < A_p < 20.0$; 5 = $20.0 < A_p < 25.0$; 6 = $A_p > 25$; 7 = AVE; 8 = MAX; (default: 1)

The CRRESPRO model uses crresproGridXDim (default: 40), crresproGridXMin (default: 1.1), crresproGridXMax (default: 5.5), crresproGridYDim (default: 60), crresproGridYMin (default: -68.0), crresproGridYMax (default: 68.0), crresproGridZDim (default: 60), crresproGridZMin (default: -180), crresproGridZMax (default: 180), and crresproOutputFile (default: crrespro.out). In addition, the following variables affect the model defaults:

crresproBModel

the default value determining which B-Field mapping is to be used. Choices are CRRESPRO_BFIELD_DIPOLE, CRRESPRO_BFIELD_TILTDIPOLE, CRRESPRO_BFIELD_TILTOFFSETDIPOLE, CRRESPRO_BFIELD_IGRF, or CRRESPRO_BFIELD_IGRFOP (default: CRRESPRO_BFIELD_IGRFOP)

crresproEnergyChannel

the default value determining which energy channel is initially predicted. Use 1 = 1.5, 2 = 2.1, 3 = 2.5, 4 = 2.9, 5 = 3.6, 6 = 4.3, 7 = 5.7, 8 = 6.8, 9 = 8.5, 10 = 9.7, 11 = 10.7, 12 = 13.2, 13 = 16.9, 14 = 19.4, 15 = 26.3, 16 = 30.9, 17 = 36.3, 18 = 41.1, 19 = 47.0, 20 = 55.0, 21 = 65.7, 22 = 81.3; (default: 1)

crresproActivity

the default value determining which Activity level is initially selected. Choices are CRRESPRO_ACTIVITY_QUIET or CRRESPRO_ACTIVITY_ACTIVE (default: CRRESPRO_ACTIVITY_QUIET)

The CRRESRAD model uses crresdoseGridXDim (default: 40), crresdoseGridXMin (default: 1.1), crresdoseGridXMax (default: 8.0), crresdoseGridYDim (default: 60), crresdoseGridYMin (default: -45.0), crresdoseGridYMax (default: 45.0), crresdoseGridZDim (default: 60), crresdoseGridZMin (default: -180), crresdoseGridZMax (default: 180), and crresdoseOutputFile (default: crresdose.out). In addition, the following variables affect the model defaults:

crresdoseBModel

the default value determining which B-Field mapping is to be used. Choices are CRRESDOSE_BFIELD_DIPOLE, CRRESDOSE_BFIELD_TILTDIPOLE,

CRRESDOSE_BFIELD_TILTOFFSETDIPOLE, CRRESDOSE_BFIELD_IGRF, or CRRESDOSE_BFIELD_IGRFOP (default: CRRESDOSE_BFIELD_IGRFOP)

crresdoseHemisphere

the default value determining which hemisphere is to be used. Choices are CRRESDOSE_HEMISPHERE_H825, CRRESDOSE_HEMISPHERE_H2325, CRRESDOSE_HEMISPHERE_H4575, or CRRESDOSE_HEMISPHERE_H8865 (default: CRRESDOSE_HEMISPHERE_H825)

crresdoseChannel

the default value determining which channel is to be used. Choices are CRRESDOSE_CHANNEL_HILOLET, CRRESDOSE_CHANNEL_LOLET or CRRESDOSE_CHANNEL_HILET (default: CRRESDOSE_CHANNEL_HILOLET)

crresdoseActivity

the default value determining which activity level is to be used. Choices are CRRESDOSE_ACTIVITY_AVERAGE, CRRESDOSE_ACTIVITY_QUIET or CRRESDOSE_ACTIVITY_ACTIVE (default: CRRESDOSE_ACTIVITY_AVERAGE)

The NASAELE model uses nasaeleGridXDim (default: 40), nasaeleGridXMin (default: 1.1), nasaeleGridXMax (default: 6.5), nasaeleGridYDim (default: 60), nasaeleGridYMin (default: -68.0), nasaeleGridYMax (default: 68.0), nasaeleGridZDim (default: 60), nasaeleGridZMin (default: -180), nasaeleGridZMax (default: 180), and nasaeleOutputFile (default: nasaele.out). In addition, the following variables affect the model defaults:

nasaeleBModel

the default value determining which B-Field mapping is to be used. Choices are NASAELE_BFIELD_DIPOLE, NASAELE_BFIELD_TILTDIPOLE, NASAELE_BFIELD_TILTOFFSETDIPOLE, NASAELE_BFIELD_IGRF, or NASAELE_BFIELD_IGRFOP (default: NASAELE_BFIELD_IGRFOP)

nasaeleEnergyChannel

the default value determining which energy channel is initially selected. Use 1 = 0.04 to 0.5, 2 = 0.65, 3 = 0.95, 4 = 1.60, 5 = 2.00, 6 = 2.35, 7 = 2.75, 8 = 3.15, 9 = 3.75, 10 = 4.55, 11 = 5.75, 12 = 6.6 to 7.0; (default: 1)

nasaeleActivity

the default value determining which Activity is initially selected. Choices are NASAELE_ACTIVITY_QUIET or NASAELE_ACTIVITY_ACTIVE, (default: NASAELE_ACTIVITY_QUIET)

The NASAPRO model uses nasaproGridXDim (default: 40), nasaproGridXMin (default: 1.1), nasaproGridXMax (default: 5.5), nasaproGridYDim (default: 60), nasaproGridYMin (default: -68.0), nasaproGridYMax (default: 68.0), nasaproGridZDim (default: 60), nasaproGridZMin (default: -180), nasaproGridZMax (default: 180), and nasaproOutputFile (default: nasapro.out). In addition, the following variables affect the model defaults:

nasaproBModel

the default value determining which B-Field mapping is to be used. Choices are NASAPRO_BFIELD_DIPOLE, NASAPRO_BFIELD_TILTDIPOLE, NASAPRO_BFIELD_TILTOFFSETDIPOLE, NASAPRO_BFIELD_IGRF, or NASAPRO_BFIELD_IGRFOP (default: NASAPRO_BFIELD_IGRFOP)

nasaproEnergyChannel

the default value determining which energy channel is initially predicted. Use 1 = 0.1 to 1.0, 2 = 1.5, 3 = 2.1, 4 = 2.5, 5 = 2.9, 6 = 3.6, 7 = 4.3, 8 = 5.7, 9 = 6.8, 10 = 8.5, 11 = 9.7, 12 = 10.7, 13 = 13.2, 14 = 16.9, 15 = 19.4, 16 = 26.3, 17 = 30.9, 18 = 36.3, 19 = 41.1, 20 = 47.0, 21 = 55.0, 22 = 65.7, 23 = 81.3, 24 = 100 to 400; (default: 1)

nasaproActivity

the default value determining which Activity level is initially selected. Choices are NASAPRO_ACTIVITY_QUIET or NASAPRO_ACTIVITY_ACTIVE, (default: NASAPRO_ACTIVITY_ACTIVE)

The PIM model uses pimGridYDim (default: 86), pimGridYMin (default: -85.0), pimGridYMax (default: 85.0), pimGridZDim (default: 73), pimGridZMin (default: -180), pimGridZMax (default: 180), and pimOutputFile (default: pim.out). In addition, the following variables affect the model defaults:

pimFoENorm

the default value determining which model for E-layer normalization is to be used. Choices are PIM_F0E_NORM_EMPIRICAL or PIM_F0E_NORM_NONE (default: PIM_F0E_NORM_NONE)

pimIMFBy

the default value of the direction of the interplanetary magnetic field Y-component. Choices are PIM_IMF_NEGATIVE or PIM_IMF_POSITIVE (default: PIM_IMF_NEGATIVE)

pimIMFBz

the default value of the direction of the interplanetary magnetic field Z-component. Choices are PIM_IMF_NEGATIVE, PIM_IMF_ZERO or PIM_IMF_POSITIVE (default: PIM_IMF_NEGATIVE)

pimF10SSNTreat

the default method of determine F10.7 and SSN Choices are PIM_SSNTREAT_DECOUPLED, PIM_SSNTREAT_COMPSSN, or PIM_SSNTREAT_COMPFTEN (default: PIM_SSNTREAT_DECOUPLED)

The WBMOD model uses wbmodGridYDim (default: 50), wbmodGridYMin (default: -89.0), wbmodGridYMax (default: 89.0), wbmodGridZDim (default: 50), wbmodGridZMin (default: -180), wbmodGridZMax (default: 180), and wbmodOutputFile (default: wbmod.out). In addition, the following variables affect the model defaults:

wbmodPropagationMode

the default value of the propagation mode switch. Choices are

WBMOD_PROPAGATE_ONEWAY or WBMOD_PROPAGATE_TWOWAY
(default: WBMOD_PROPAGATE_ONEWAY)

wbmodCorrelationFactor

the default value of the correlation factor for the up/down link in two-way propagation
(default: 1.0)

wbmodDriftVelocityMode

the default value of the switch for determining the drift velocity. Choices are
WBMOD_DRIFT_VELOCITY_INPUT or WBMOD_DRIFT_VELOCITY_MODEL.
(default: WBMOD_DRIFT_VELOCITY_MODEL)

wbmodDriftNorth

the default value of the north drift velocity used when the drift velocity is specified.
(default: 0.0)

wbmodDriftEast

the default value of the east drift velocity used when the drift velocity is specified.
(default: 0.0)

wbmodDriftDown

the default value of the down drift velocity used when the drift velocity is specified.
(default: 0.0)

wbmodEPModel

the default value of the model to use to specify the electron precipitation boundary.
Choices are WBMOD_EP_MODEL_EFFKP, WBMOD_EP_MODEL_EXPLICIT or
WBMOD_EP_MODEL_GLOBALKP (default: WBMOD_EP_MODEL_GLOBALKP)

wbmodSunsetKp

the default value of the Kp at local sunset. Use -1.0 to use global Kp. (default: -1.0)

wbmodEffectiveKp

the default value of the effective Kp if the electron precipitation boundary mode is set to
Effective Kp. (default: 3.0)

wbmodEPMagLat

the default value of the magnetic latitude of the electron precipitation boundary, used then the
EPMode is set to Explicit. (default: 62.0)

wbmodEPMagLocTime

the default value of the magnetic local time of the electron precipitation boundary, used then
the EPMode is set to Explicit. (default: 0.0)

wbmodMover

the default value of the switch specifying whether the transmitter or receiver should be
stepped. Choices are WBMOD_MOVER_RCVR or WBMOD_MOVER_TRANS
(default: WBMOD_MOVER_TRANS)

wbmodOutputType

the default value of the switch specifying the output type. Choices are
WBMOD_OUTPUT_TYPE_THRESHOLD or WBMOD_OUTPUT_TYPE_PERCENT.
(default: WBMOD_OUTPUT_TYPE_PERCENT)

wbmodThresholdType

the default value of the switch specifying which parameter to threshold on. Choices are
WBMOD_THRESHOLD_TYPE_PHASE or WBMOD_THRESHOLD_TYPE_S4
(default: WBMOD_THRESHOLD_TYPE_S4)

wbmodThresholdValue

the default value of the threshold (when output type is Threshold) or the default percentile
(when output type is Percentile) (default: 0.8)

wbmodFixedEndLat

the default value of the latitude of the fixed end. (default: 0.0)

wbmodFixedEndLong

the default value of the longitude of the fixed end. (default: -120.0)

wbmodTransmitterFreq

the default value of the transmitter frequency (default: 250.0)

wbmodTransmitterAlt

the default value of the transmitter altitude (default: 36000.0)

wbmodPhaseDuration

the default value of the phase stability required (default: 10.0)

Parameters from WBMGRID augment the functionality of the WBMOD model and include the use of wbmgridOutputFile (default: wbmgrid.out). In addition, the following variables affect the model defaults:

wbmgridDriftVelocityMode

the default value of the switch for determining the drift velocity. Choices are
WBMOD_DRIFT_VELOCITY_INPUT or WBMOD_DRIFT_VELOCITY_MODEL.
(default: WBMOD_DRIFT_VELOCITY_MODEL)

wbmgridDriftNorth

the default value of the north drift velocity used when the drift velocity is specified
(default: 0.0)

wbmgridDriftEast

the default value of the east drift velocity used when the drift velocity is specified
(default: 0.0)

wbmgridDriftDown

the default value of the down drift velocity used when the drift velocity is specified

(default: 0.0)

wbmgridVSatNorth

the default value of the north satellite velocity used when the satellite velocity is specified
(default: 0.0)

wbmgridVSatEast

the default value of the east satellite velocity used when the satellite velocity is specified
(default: 4000.0)

wbmgridVSatDown

the default value of the down satellite velocity used when the satellite velocity is specified
(default: 0.0)

wbmgridEPModel

the default value of the model to use to specify the electron precipitation boundary. Choices are WBMOD_EP_MODEL_EFFKP, WBMOD_EP_MODEL_EXPLICIT or WBMOD_EP_MODEL_GLOBALKP. (default: WBMOD_EP_MODEL_GLOBALKP)

wbmgridSunsetKp

the default value of the Kp at local sunset. Use -1.0 to use global Kp (default: -1.0)

wbmgridEffectiveKp

the default value of the effective Kp if the electron precipitation boundary mode is set to Effective Kp (default: 3.0)

wbmgridEPMagLat

the default value of the magnetic latitude of the electron precipitation boundary, used when the EPMode is set to Explicit (default: 62.0)

wbmgridEPMagLocTime

the default value of the magnetic local time of the electron precipitation boundary, used when the EPMode is set to Explicit. (default: 0.0)

wbmgridThresholdValue

the default value of the threshold (when output type is Threshold) or the default percentile (when output type is Percentile) (default: 0.8)

wbmgridFixedEndLat

the default value of the latitude of the fixed end (default: 0.0)

wbmgridFixedEndLong

the default value of the longitude of the fixed end (default: -120.0)

wbmgridTransmitterFreq

the default value of the transmitter frequency (default: 250.0)

wbmgridTransmitterAlt

the default value of the transmitter altitude (default: 36000.0)

The BFIELD-APP model uses bfieldappGridXDim (default: 40), bfieldappGridXMin (default: 1.1), bfieldappGridXMax (default: 5.0), bfieldappGridYDim (default: 40), bfieldappGridYMin (default: -89.0), bfieldappGridYMax (default: 89.0), bfieldappGridZDim (default: 40), bfieldappGridZMin (default: -180), bfieldappGridZMax (default: 180), and bfieldappOutputFile (default: bfieldapp.out). In addition, the following variables affect the model defaults:

bfieldappDoGridded

boolean value: true if the B-field should be calculated on the grid (default: true)

bfieldappDoMLTLines

boolean value: true if the B-field lines should be calculated at constant MLT (default: true)

bfieldappDoMLATLines

boolean value: true if the B-field should be calculated at constant MLAT (default: false)

bfieldappDoFluxTube

boolean value: true if the a flux tube should be calculated (default: false)

bfieldappIntField

the default internal field used by the BFIELDAPP module. Choices are DIPOLE_INT_FIELD, IGRF_INT_FIELD or FAST_IGRF_INT_FIELD.
(default: DIPOLE_INT_FIELD)

bfieldappExtField

the default external field used by the BFIELDAPP module. Choices are NO_EXT_FIELD, HILMER_VOIGT_EXT_FIELD, OLSON_PFITZER_EXT_FIELD, TSYGANENKO_1989_EXT_FIELD, or TSYGANENKO_1987_EXT_FIELD.
(default: NO_EXT_FIELD)

bfieldappHVMode

the default mode used by the BFIELDAPP module with the Hilmer-Voigt external field. Choices are KP_ONLY HV_MODE, DST_EQEDGE_STANDOFF_HV_MODE, or VACUUM_HV_MODE. (default: KP_ONLY_HV_MODE)

bfieldappDstModel

the default value of the discrete Dst model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = -600; 1 = -500.0; 2 = -400; 3 = -300; 4 = -200; 5 = -150; 6 = -100; 7 = -50; 8 = 0; 9 = 50; (default: 5)

bfieldappEqEdgeModel

the default value of the discrete equatorward edge model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = 34.38, 1 = 43.93, 2 = 49.47, 3 = 53.20, 4 = 55.89, 5 = 57.96, 6 = 59.60, 7 = 60.95, 8 = 62.06, 9 = 63.02, 10 = 63.99, 11 = 65.01, 12 = 65.91, 13 = 66.72, 14 = 67.45, 15 = 68.12, 16 = 68.73, 17 = 69.30; (default: 8)

bfieldappStandoffModel

the default value of the discrete standoff distance model when using Hilmer-Voigt in Standoff, Dst, Equatorward Edge mode. Use 0 = 4.0; 1 = 6.0; 2 = 8.0; 3 = 10.0; 4 = 12.0; 5 = 14.0; (default: 3)

bfieldappStandoffValue

the default value of the standoff distance when using Hilmer-Voigt in Vacuum Config mode. Use $4 < \text{Standoff} < 14$. (default: 10.0)

bfieldappT89Mode

the default mode for the Tsyanenko '89 model. Choices are KP_ONLY_T89_MODE or AE_ONLY_T89_MODE; (default: KP_ONLY_T89_MODE)

bfieldappAeModel

the default value of the discrete Ae range when using the Tsyanenko '89 model in Ae Only mode. Use 0 = $0 < \text{Ae} < 50$; 1 = $50 < \text{Ae} < 100$; 2 = $100 < \text{Ae} < 150$; 3 = $150 < \text{Ae} < 250$; 4 = $250 < \text{Ae} < 400$; 5 = $400 < \text{Ae}$; (default: 0)

bfieldappMLT

the default value of the magnetic local time at which to calculate MLT Field Lines. (default: 0)

bfieldappMLAT0

the default value of the minimum magnetic latitude at which to calculate MLT Field Lines. (default: 5.0)

bfieldappMLAT1

the default value of the maximum magnetic latitude at which to calculate MLT Field Lines. (default: 85.0)

bfieldappMLATSteps

the default value of the number of magnetic latitudes at which to calculate MLT Field Lines. (default: 8)

bfieldappMLAT

the default value of the magnetic latitude at which to calculate MLAT Field Lines. (default: 70)

bfieldappMLT0

the default value of the minimum magnetic local time at which to calculate MLAT Field Lines. (default: 0)

bfieldappMLT1

the default value of the maximum magnetic local time at which to calculate MLAT Field Lines. (default: 24)

bfieldappMLTSteps

the default value of the number of magnetic local times at which to calculate MLAT Field

Lines. (default: 24)

bfieldappFTCoords

the default value of the flux tube input coordinate system. Choices are BFIELD_FT_COORD_GEOM or BFIELD_FT_COORD_GEOG (default: BFIELD_FT_COORD_GEOG)

bfieldappFTLat

the default value of the latitude of the center of the flux tube, used when calculating a flux tube in geographic coordinates (default: 70)

bfieldappFTLon

the default value of the longitude of the center of the flux tube, used when calculating a flux tube in geographic coordinates (default: 0)

bfieldappFTAlt

the default value of the altitude of the flux tube is specified at, used when calculating a flux tube in geographic coordinates (default: 0)

bfieldappFTDiam

the default value of the diameter of the flux tube, used when calculating a flux tube in geographic coordinates (default: 200)

bfieldappFTMLT

the default value of the magnetic local time of the center of the flux tube, used when calculating a flux tube in geomagnetic coordinates (default: 0)

bfieldappFTMLAT

the default value of the magnetic latitude of the center of the flux tube, used when calculating a flux tube in geomagnetic coordinates (default: 70)

bfieldappFTRadius

the default value of the altitude the center of the flux tube is specified at (in R_e), used when calculating a flux tube in geomagnetic coordinates (default: 1.)

bfieldappFTMDiam

the default value of the diameter of flux tube (in degrees) used when calculating a flux tube in geomagnetic coordinates (default: 2.)

bfieldappFTSteps

the default value of the number of field lines which should be used to represent a flux tube (default: 20)

The SATEL-APP model uses orbitappOutputFile (default: orbitapp.out). The SATEL-APP defaults are also used by CRRESELE-APP, CRRESPRO-APP and CRRESRAD-APP. In addition to orbitappOutputFile, the following variables affect the model defaults:

orbitappPropagator

the default value of the switch of the orbit propagator to use in calculations. Choices are ORBITAPP_PROPAGATOR_LOKANGLE or ORBITAPP_PROPAGATOR_SGP4
(default: ORBITAPP_PROPAGATOR_LOKANGLE)

orbitappEphemerisFile

the default name of the file from which to build the list of orbits. An empty value will use the file "tle.new" in the directory \$(PLGS_MODELS)/MODELS/data/EPHEMERIS.
(default: "")

orbitappSatName

the default name of the satellite used when mean or PV elements are specified.
(default: ORBIT)

orbitappTRef

the default value of the reference time of the ephemeris. (default: 94221.65625)

orbitappTStart

the default value of the starting time of the orbit calculation. A value of 0.0 will use TRef.
(default: 0.)

orbitappTStop

the default value of the stopping time of the orbit calculation. A value of 0.0 will use TRef + 1 day. (default: 0.)

orbitappDT

the default value of the time step of the orbit calculation. (default: 60.0)

orbitappInclination

the default value of the inclination of the orbit, used when MEAN elements are specified.
(default: 69.976)

orbitappRightAscension

the default value of the right ascension of the orbit, used when MEAN elements are specified.
(default: 234.104)

orbitappEccentricity

the default value of the eccentricity of the orbit, used when MEAN elements are specified.
(default: 0.14)

orbitappArgOfPerigee

the default value of the argument of perigee of the orbit, used when MEAN elements are specified. (default: 150.86)

orbitappMeanMotion

the default value of the mean motion of the orbit, used when MEAN elements are specified.
(default: 12.525)

orbitappMeanAnomaly

the default value of the mean anomaly of the orbit, used when MEAN elements are specified. (default: 257.732)

orbitappDotMeanMotion

the default value of one-half the derivative of the mean motion of the orbit, used when MEAN elements are specified. (default: 0.000001)

orbitappDoubleDotMeanMotion

the default value of one-sixth the second derivative of the mean motion of the orbit, used when MEAN elements are specified. (default: 0.000001)

orbitappBStar

the default value of the BSTAR drag term of the orbit, used when MEAN elements are specified. (default: 0.000001)

orbitappPX0

the default value of the X-position of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: -2743.92)

orbitappPY0

the default value of the Y-position of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: -6445.46)

orbitappPZ0

the default value of the Z-position of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: 4270.25)

orbitappVX0

the default value of the X-velocity of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: 4.04771)

orbitappVY0

the default value of the Y-velocity of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: 2.60426)

orbitappVZ0

the default value of the Z-velocity of the satellite at TRef, specified in ECI coordinates and used when PV elements are specified. (default: 4.8049)

orbitappPeriodDecay

the default value of the period decay of the orbit, used when PV elements are specified. (default: 0.000001)

Examples

This section provides several extremely well detailed examples demonstrating the modeling and display capability of AF-GEOSpace. It is the authors' belief that the most efficient way to learn the program is by working through an example or two.

The following examples are given below:

- 1. Space Particle Hazards**
- 2. Low Earth Orbit Particle Environment**
- 3. Low Earth Orbit Total Dose**
- 4. Single Event Upset Environment**
- 5. The Earth's Magnetic Field: Placement of the Current Sheet**
- 6. UHF/L-Band Scintillation on a Geostationary Satellite Downlink**
- 7. The Magnetospheric Cusp and Auroral Equatorward Boundary**
- 8. Auroral Radar Clutter**
- 9. HF Ray-Tracing in the Ionosphere**
- 10. Outer Zone Energetic Electron Dynamics**
- 11. The Energetic Solar Event of 20 February 1994**

Note: There are a number of ready-made AF-GEOSpace scripts that can be used to quickly generate several specific environments, including some of those constructed in the above examples. These scripts (always ending with '.gs') are located in the directory \$AFGS_HOME/PLGS/examples and can be run using the *Load as* function described in the *Environments* section of this document. Note that while not all graphical features (e.g., links, detector cones, captions, and special color choices) are recreated using the script process, many of them can be reintroduced after the run is complete.

1) Space Particle Hazards

The following example demonstrates the use of the DMSP aurora Science Module (AURORA), the CRRES electron and proton radiation belt flux Science Modules (CRRESELE, CRRESPRO), the Satellite Application Module (SATEL-APP), and a variety of visualization tools including animated satellite orbits, links, and detector cones.

Goal: View auroral electron precipitation patterns and the 3-D distribution of 1.6 MeV electron and 10.7 MeV proton radiation belt fluxes during magnetically active times relative to spacecraft in Low, Medium, Geosynchronous, and High Earth Orbit (a.k.a., LEO, MEO, GEO, HEO). Build satellite-to-ground communications links and satellite detector cones.

Start a GEOSpace session and set global input parameters,

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: “AFGS”. The Welcome Window will appear (the red frame fills in after clicking the left mouse button). Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Set the date and time in the Environment Window by editing the text boxes to read: “Year”=1996, “Day”=315, and “UT”=18:00. Click on the *Archive* option showing in the *Globals* button and the values of the Kp geomagnetic index, sunspot number (SSN), F10.7 cm radio flux, and the Ap geomagnetic index for this time will be copied from archived NGDC parameters (“Kp”=1.7, “SSN”=12, “F10.7”=69.6, and “Ap”=6). Reset “Kp”=5.0 and “Ap”=25 to represent a magnetically active period by manually editing the corresponding text boxes.

Create a 3-D graphic of the Earth with the Air Force Research Laboratory location displayed,

- From the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window for displaying 3D gridded data sets will appear.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of EARTH Options will appear in the bottom of the Environment Window.
- Under “Outline Detail”, select *Geographic Bndys* and *Locations*. Under “Grid Options” select *Lat/Lon Grid*. The less detail shown on the Earth, the faster the response for its 3D manipulation. Below the “Detail Level” slider, click on the *Locations* button and a popup window with a *Stations* list will appear. Click on the *Create* button and edit the text boxes in the popup window that appears such that “Label”=AFRL, “Altitude(km)”= 0.0, “Lat(N)”= 42.30, and “Lon(E)”= -71.05. Click the *Accept* button to close the window. An AFRL entry should now

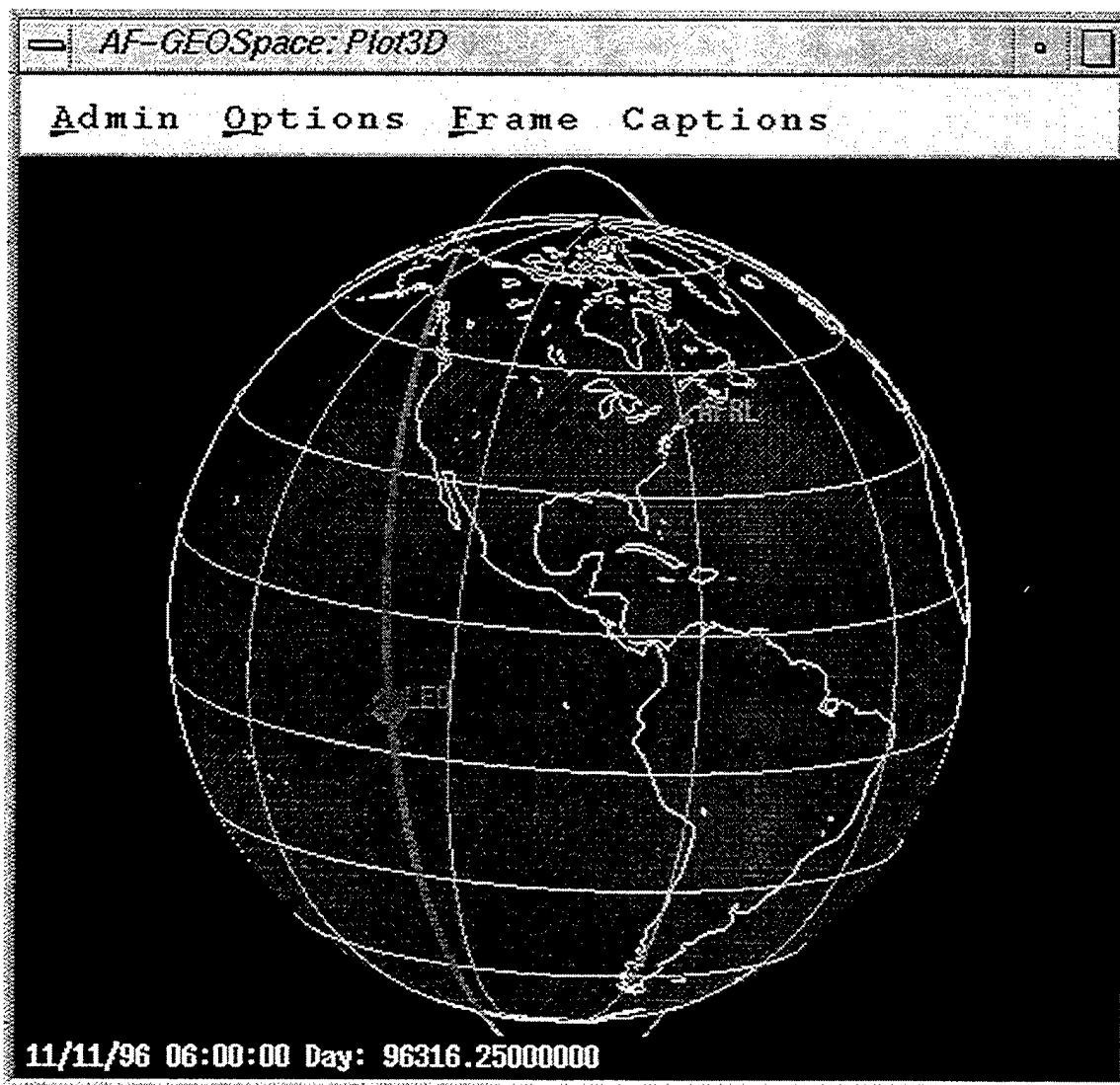
be in the *Stations* list marked by an asterisk (stations marked by an asterisk will appear in our image of Earth. To display other listed stations, highlight their entries and click the *Add* button.) By highlighting the “*AFRL” entry, the geographic location details just recorded appear to the right. Click the *Done* button to close the location popup window.

- Click on *PLOT3D* in the *Display In* list at the bottom of the Environment Window and a globe will appear in the Plot3D Window. With no data plotted, the color bar in the window has no units so we will remove it. From the Plot3D Window *Options* menu, turn off *Show Color Bar*.
- The Earth’s size can be scaled in the Plot3D Window using the middle mouse button. With the cursor in the Plot3D Window, depress the middle button and draw the mouse toward yourself. Rotate the Earth so that the AFRL location marker is visible by depressing the left button and moving the mouse sideways. (Mouse control hints are displayed by pulling down the Plot3D Window *Options* menu and selecting *Show Hints*).

Create and display an orbiting Low Earth Orbit (LEO) satellite,

- Choose *Modules* from the Menu Bar of the Environment Window and select *Applications*. *Available Application Modules* and *Active Application Modules* lists will appear.
- Scroll down the *Available Application Modules* list and click on *SATEL-APP*. A SATEL-APP object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Under “Propagator” leave the *Lokangle* option set and under “Element Type” choose the *Mean* option. Edit the text boxes that appear so that “Inclination”=98.583, “Arg. of Peri-gee”=114.661, “Mean Anomaly”=246.292, “Eccentricity”=0.0008, “R.A. Asc. Node”=19.714, and “Mean Motion” = 14.327 (leave “d(MM)/dt/2”, “d2(MM)/dt2/6”, and “BSTAR” at their default values). Set the orbit reference time by editing the “T_ref” text box to read “11/04/96 19:48:29”. Type “LEO” in the “Sat. Name” text box and leave “Time Step (s)” set at 60 seconds.
- Click the *Run Model* button. A red Wait Window will appear as orbit data are generated.
- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Scroll down the *Available Graphics Modules* list and select *SATELLITE*. A SATELLITE object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Click on the “Orbit” button and select the option *LEO*, leave “Data” set to *off*, use the “Label” button to select *Sat. Name*, and check *Pop Marker*. Under “Reference Frame” place a check next to *Inertial (ECI)* and uncheck *Geocentric (GEOC)*. Click on *PLOT3D* in the *Display In* box. The LEO satellite will appear in orbit near the equator over the Pacific Ocean in the Plot3D Window. Click on the *Marker* button and Marker Parameters appear at the bottom of the Environment Window. Use the *Radius* slider to reduce the satellite marker size to 0.05 Re.

- Choose *Windows* from the Environment Window Menu Bar and select the *Animation* option and an Animation Window will appear. Click the *Find Range* button to allow the animator to register the times span covered by the orbit generated. Move the *Time* slider to the value 0.500, corresponding to "11/11/96 06:00", and the Plot3D Window should resemble the figure below. Remember, you can use the left and center mouse buttons to rotate and scale the image, respectively. (Control hints are displayed by selecting *Show Hints* from the *Options* menu).



- Click the *Start/Continue* button and the changing LEO satellite position will be displayed at 300 second intervals. Click the *Pause* button to halt the animation. The *Exit / Reset to Globals* button will halt the animation and dismiss the Animation Window.

Create and display an AURORA Science Module data set,

- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Science*. *Available Science Modules* and *Active Science Modules* lists will appear.

- Click on *AURORA* in the *Available Science Modules* list. An AURORA object will be added to the *Active Science Modules* list and a set of AURORA Options will appear in the bottom of the Environment Window.
- Leave the “Generate” and the “External B-Field” options at their default values. Set “Internal B-Field” to the *Fast IGRF* option. Leave the “Equatorward Edge Parameters” and “Model” option sections set at the default values.
- Click on the *Run Model* button at the bottom of the Environment Window. A red Wait Window will appear temporarily. When the model is complete the Wait Window will disappear and the *Model Status* box will indicate that the Global Parameters “Day”, “Time”, and “Kp” were used and that the “MODEL IS READY AND UP TO DATE.”
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Scroll up the *Available Graphics Modules* list, select *COORD-SLICE*, and a COORD-SLICE object will be added to the *Active Graphics Modules* list. A set of Coordslice Options will appear in the Environment Window. The coordinate parameters *C0*, *C1*, and *C2* correspond to the three spherical coordinates used when building the aurora data set. Use the default setting under “Coordinate” called *C0* to slice the data at a constant radius.
- Click the *Data* button, go to the *AURORA* option, and select *Elec. Number Flux*. Click anywhere on the window background to register your choice. Click on *PLOT3D* in the *Display In* list at the bottom of the Environment Window and auroral electron data will appear in the Plot3D Window. From the Plot3D Window menu bar, use the *Options* menu to again *Show Color Bar*. The units for the color bar now represent auroral electron number flux.
- To make the auroral display more transparent, click the *Transp.* button in the Environment Window and move the *Alpha Value* slider to a value of 0.70. Rotate the Earth and notice that the auroral electron number flux is displayed at both poles.

Create a CRRESELE Science Module data set,

- Choose *Modules* from the Environment Window Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *CRRESELE* in the *Available Science Modules* list. A CRRESELE object will be added to the *Active Science Modules* list and a set of CRRESELE Options will appear in the Environment Window.
- Click on the *B-Model* button and select *Dip-Tilt-Off*. This is not the magnetic field model originally used to reduce the CRRES data but will suffice for this example. From the *Energy Channel* list, select *1.6 MeV* and from the *Ap15 Model Range* list, select the *Ap15 20.0 - 25.0* option. Leave the *Compute* button alone.
- Click on the *Run Model* button at the bottom of the window. A red Wait Window will appear while CRRESELE is running. When the model is complete the Wait Window will disappear

and the model inputs will appear in the *Model Status* box at the bottom of the Environment Window with the message “MODEL IS READY AND UP TO DATE.”

Display two CRRESELE data coordinate slices at constant longitude,

- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- A COORD-SLICE entry is currently highlighted in the *Available Graphics Modules* list from its use for AURORA. Click twice on *COORD-SLICE* from the *Available Graphics Modules* list and a second COORD-SLICE object will be added to the *Active Graphics Modules* list. A set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select *Flux* under the CRRESELE option. Click on the window background to register your choice. Select the “Coordinate” C2 to slice the CRRESELE data at a constant longitude. Click on *PLOT3D* in the *Display In* list and CRRESELE data appear near 0 degrees Longitude. Move the *Position Value* slider until the longitude value displayed under the slider is approximately “Lon 3 Deg E”. Notice that the color bar units now represent CRRESELE electron number flux. In general, the color bar units correspond to the graphics object currently highlighted in the *Active Graphics Modules* list.
- Click twice on *COORD-SLICE* in the *Available Graphics Modules* list and a third COORD-SLICE object will be added to the *Active Graphics Modules* list. A set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select *Flux* under the CRRESELE option. Click on the window background to register your choice. Select the “Coordinate” option C2, click on *PLOT3D* in the *Display In* list, and CRRESELE data appears again near 0 degrees Longitude to overlay the first. Move the *Position Value* slider to approximately “Lon -177 Deg E”. There are now two electron belt coordinate slices on opposite sides of the Earth.

Create a CRRESPRO Science Module data set,

- Choose *Modules* from the Environment Window Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *CRRESPRO* in the *Available Science Modules* list. A CRRESPRO object will be added to the *Active Science Modules* list and a set of CRRESPRO Options will appear in the Environment Window.
- Click on the *B-Model* button and select *Dip-Tilt-Off*. Again, this is not the magnetic field model originally used to reduce the CRRES data but will suffice for this example. From the *Energy Channel* list select 10.7 MeV and use the *Activity* button to select the *Active* option.
- Click on the *Run Model* button at the bottom of the window. A red Wait Window will appear while CRRESPRO is running. When the model is complete the Wait Window will disappear and the model inputs will appear in the *Model Status* box at the bottom of the Environment Window along with the message “MODEL IS READY AND UP TO DATE.”

Display two CRRESPRO data coordinate slices at constant longitude,

- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Click twice on *COORD-SLICE* in the *Available Graphics Modules* list and a fourth *COORD-SLICE* object will be added to the *Active Graphics Modules* list. A set of *Coordslice Options* will appear in the Environment Window.
- Click the *Data* button and select *Flux* under the CRRESPRO option. Click on the window background to register your choice. Select the “Coordinate” *C2* to slice the CRRESPRO data at a constant longitude. Click on *PLOT3D* in the *Display In* list and CRRESPRO data appears near 0 degrees Longitude. Move the *Position Value* slider to approximately “Lon +5 Deg E” and the proton coordinate slice will be just westward of one of the electron coordinate slices. The units for the color bar now represent CRRESPRO proton number flux.
- Click twice on *COORD-SLICE* in the *Available Graphics Modules* list and a fifth *COORD-SLICE* object will be added to the *Active Graphics Modules* list. A set of *Coordslice Options* will appear in the Environment Window.
- Click the *Data* button and select *Flux* under the CRRESPRO option. Click on the window background to register your choice. Select the “Coordinate” *C2* to slice the data at constant longitude and click on *PLOT3D* in the *Display In* list. CRRESPRO data appears again near 0 degrees Longitude. Move the *Position Value* slider to read approximately “Lon 180 Deg E”.
- To make more room for the data displayed, go to the Plot3D Window and use the *Options* menu to turn off the *Show Color Bar* feature.

Create and display a Medium Earth Orbit (MEO) data set with a communications link to AFRL,

- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Click twice on *SATEL-APP* in the *Available Application Modules* list. A second *SATEL-APP* object will be added to the *Active Application Modules* list and a set of *Ephemeris Data* options will appear in the Environment Window.
- Under “Propagator” leave *Lokangle* selected and under “Element Type” choose the option *Mean*. Edit the text boxes that appear so that “Inclination”=55.057, “Arg. of Perigee” = 203.685, “Mean Anomaly”=156.036, “Eccentricity”=0.007, “R.A. Asc. Node”=314.183, and “Mean Motion” = 2.006 (leave “d(MM)/dt/2”, “d2(MM)/dt2/6”, and “BSTAR” at their default values. Edit the orbit reference time so that the “T_ref” text box reads “11/04/96 08:44:20”. Type “MEO” in the “Sat. Name” text box and leave “Time Step (s)” set at 60 seconds.
- Click the *Links...* button, highlight the AFRL entry in the *Stations* list, click the *Add Link* button and then the *Accept* button to close the links popup window.
- Click the *Run Model* button. A red Wait Window will appear as orbit data are generated.

- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Scroll down the *Available Graphics Modules* list and click on *SATELLITE*. A *SATELLITE* object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Use the *Orbit* button to select *MEO*, leave “Data” set to *off*, use the *Label* button to select *Sat. Name*, and check *Pop Marker*. Under “Reference Frame”, check *Inertial (ECI)* and uncheck *Geocentric (GEOC)*. Click the *Links* button and highlight the *AFRL* entry, click *Done*. Click on *PLOT3D* in the *Display In* box. The *MEO* orbit will appear in the *Plot3D* Window (you may need to rescale the plot to see it). Click on the *Marker* button and use the *Radius* slider to reduce the satellite marker size to 0.05 Re.
- Move the *Satellite position (%)* slider to move the satellite and notice that the link line will appear only when the *MEO* satellite is within line-of-sight of *AFRL*.

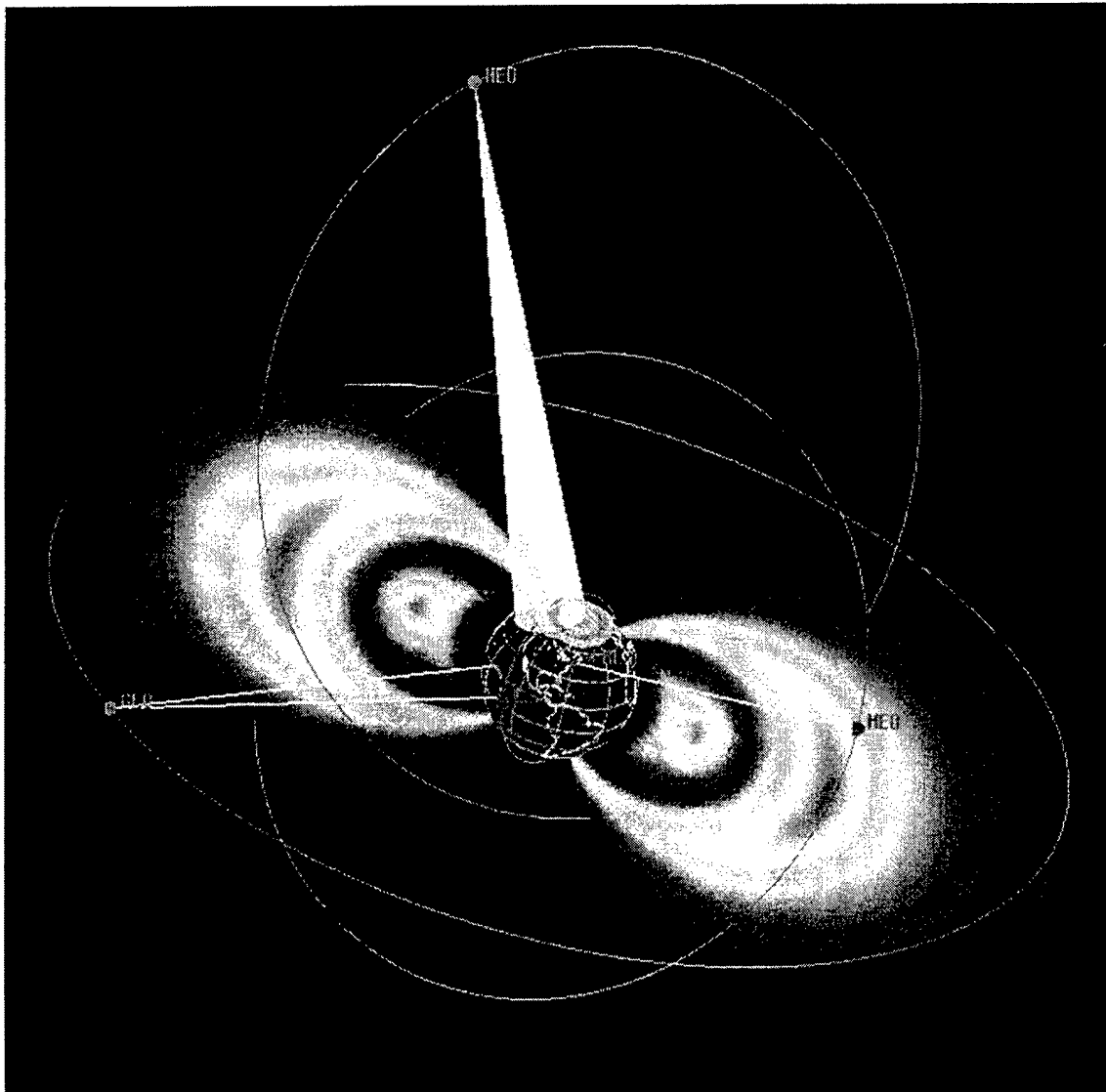
Create and display a High Earth Orbit (HEO) data set with a downward looking detector cone,

- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Click twice on *SATEL-APP* in the *Available Application Modules* list. A third *SATEL-APP* object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Under “Propagator” leave the *Lokangle* option selected and choose *Mean* under “Element Type”. Edit the text boxes that appear so that “Inclination”=86.302, “Arg. of Perigee”=278.085, “Mean Anomaly”=22.234, “Eccentricity”=0.6338, “R.A. Asc. Node”=24.922, and “Mean Motion” = 1.362 (leave “d(MM)/dt/2”, “d2(MM)/dt2/6”, and “BSTAR” at their default values). Adjust the orbit reference time by editing the “T_ref” text box to read “10/29/96 17:06:38”. Type “HEO” in the “Sat. Name” text box and leave “Time Step (s)” set at 60.
- To create a detector device and associate it with the HEO satellite perform the following steps: Click the *Detectors* button (an error popup window may appear if this is the first time a detector device is created. It can be dismissed by clicking the *OK* button), click the *Add Device* button in the *Satelapp* Window and another popup window appears. Edit the “Device Name” text box to read “Down-fov7”, select the “Detector Type” option called *Fixed Pointing Angle*, enter 0 degrees for both the “Detector Pitch Angle” and “Detector Azimuth Angle”, move the *Detector Field of View (deg)* slider to read 7, and click the *OK* button. A “Down-fov7” entry appears in the *Devices* list. Highlight this new entry and click the *Add Detector* button to associate the device with HEO. Click the *Accept* button and the *Satelapp* Window vanishes.
- Click the *Run Model* button. After the *Wait Window* vanishes the *Model Status* box will indicate that the “MODEL IS READY AND UP TO DATE.”
- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.

- Click twice on *SATELLITE* in the *Available Graphics Modules* list. A third *SATELLITE* object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Select HEO with the *Orbit* button, leave the *Data* button set to *off*, use the *Label* button to select *Sat. Name*, and check *Pop Marker*. Under “Reference Frame” check *Inertial (ECI)* and uncheck *Geocentric (GEOC)*. Click the *Detectors* button, highlight the “Down-fov7” entry in the detector dialog window, and click the *Done* button. Click on *PLOT3D* in the *Display In* box and the HEO orbit with detector cone will appear in the Plot3D Window. Put a check next to *Solid Detector* (lower left) and click the *Update* button to make the cone solid. Click the *Transp.* button, move the *Alpha Value* slider to 0.70, and click on *Update* to make the cone slightly transparent. Click on the *Marker* button and use the *Radius* slider to reduce the satellite marker size to 0.05 Re.

Create and display a Geosynchronous Orbit (GEO) data set with a detector cone,

- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Click twice on *SATEL-APP* in the *Available Application Modules* list. A fourth *SATEL-APP* object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Under “Propagator” leave *Lokangle* selected and choose *Mean* under “Element Type”. Edit the text boxes that appear so that “Inclination”=0.1233, “Arg. of Perigee”=332.651, “Mean Anomaly”=263.618, “Eccentricity”=0.0004, “R.A. Asc. Node”=266.253, and “Mean Motion”= 1.003 (leave “d(MM)/dt/2”, “d2(MM)/dt/6”, and “BSTAR” at their default values). Edit the orbit reference time so that the “T_ref” text box reads “11/04/96 15:31:55”. Type “GEO” in the “Sat. Name” text box and leave “Time Step (s)” set at 60 seconds.
- To create a detector device and associate it with the GEO satellite perform the following steps: Click the *Detectors* button, click the *Add Device* button in the *Satelapp* Window and another popup window appears. Edit the “Device Name” text box to read “Down-fov4”, select the “Detector Type” option called *Fixed Pointing Angle*, enter 0 degrees for both the “Detector Pitch Angle” and “Detector Azimuth Angle”, move the *Detector Field of View (deg)* slider to read 4, and click the *OK* button. A “Down-fov4” entry now appears in the *Devices* list. Highlight this new entry and click the *Add Detector* button. Click the *Accept* button.
- Click the *Run Model* button. A Wait Window appears briefly and the *Model Status* box will indicate “MODEL IS READY AND UP TO DATE.”
- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Click twice on *SATELLITE* in the *Available Graphics Modules* list. A fourth *SATELLITE* object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.



- Use the *Orbit* button to select *GEO*, leave the *Data* button set to *off*, use the *Label* button to select *Sat. Name*, and check *Pop Marker*. Under “Reference Frame” check *Inertial (ECI)* and uncheck *Geocentric (GEOC)*. Click the *Detectors* button, highlight the “Down-fov4” entry in the detector dialog window, and click the *Done* button. Click on *PLOT3D* in the *Display In* box and the GEO orbit with detector cone will appear over the Pacific Ocean in the Plot3D Window. Click on the *Marker* button and use the *Radius* slider to reduce the satellite marker size to 0.05 Re. The plot should resemble the figure above.

While the HEO detector is scanning the aurora over Alaska, the MEO satellite is entering the heart of the 1.6 MeV electron radiation belt and is in line-of-sight of AFRL. The LEO satellite is moving southward over equator in the Pacific while the GEO satellite detector is still monitoring a nearby patch of open water.

Animate the LEO, MEO, GEO, HEO satellite constellation,

- Once again, choose *Windows* from the Menu Bar and select *Animation* from the options. The Animation Window will appear. Move the *Time* slider until it reads 0.125 (equivalent to the date and time 11/10/96 21:00) and the Plot3D Window satellite positions should match those of the figure above. Note that we did not have to use the *Find Range* button this time because the range was properly set earlier in this example. Remember, you can use the left and center mouse buttons to rotate and scale the image, respectively.
- Click the *Start/Continue* button in the Animation Window and all satellite orbits will be displayed at 300 second intervals. While the two detector cones shine continuously, the MEO-AFRL link appears only when line-of-sight communication is possible. Click the *Pause* button to pause the motion or *Exit / Reset to Globals* button to halt the animation and dismiss the Animation Window.

This completes the Example of Space Particle Hazards.

2) Low Earth Orbit Particle Environment

The following example demonstrates the use of the CRRES proton (CRRESPRO) and the CRRES electron (CRRESELE) radiation belt flux Science Modules, the DMSP aurora Science Module (AURORA), the Satellite Application Module (SATEL-APP), and a variety of graphical tools.

Goal: Demonstrate the spatial distribution of the particle populations encountered by the Defense Meteorological Satellite Program (DMSP) satellite (in a low Earth orbit), including the low altitude projections of the inner and outer radiation belts as well as the auroral oval. It will be shown that the inner belt protons penetrate to DMSP altitude in a localized region above the South Atlantic (South Atlantic Anomaly) due to the asymmetry of the Earth's magnetic field. A low altitude projection of the outer radiation belt electrons appears in both hemispheres, and the particle flux from the magnetosphere's plasma sheet precipitates into the ionosphere forming the high latitude auroral oval. Both a 2D and a 3D representation of these populations, along with a trace of a DMSP orbit, will be shown juxtaposed over the Earth. 1D flux plots versus time will also be generated for each of the three populations.

Procedure Summary: Section 1 starts a Static Model session, Sections 2-4 generate the CRRESPRO, CRRESELE, and AURORA Science Module data sets, Section 5 generates the DMSP orbit data set, Section 6 creates a 2D and a 3D view of the Earth with a superimposed DMSP orbit, Section 7 creates a 2D view of the particle environment, Section 8 creates a 3D view of the particle environment, and Section 9 creates a 1D plot of flux vs. time for the DMSP orbit.

1) Start a GEOSpace session and set global input parameters,

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Set the date and time by editing the Globals text boxes to read: "Year" = 1997, "Day" = 200, and "UT" = 10:30 (Day 200 = 19 July). Click on the *Archive* option of the *Globals* button and the values of the Kp geomagnetic index, sunspot number (SSN), F10.7 cm radio flux, and the Ap geomagnetic index that have been archived by NGDC will be retrieved for the appropriate time ("Kp"=1.7, "SSN"=0, "F10.7"=72.8, and "Ap"=6). Although *Archive* is the default setting, it must be clicked to activate the retrieval of the archived indices.

2) Create a CRRESPRO Science Module (inner proton belt) data set,

- Choose *Modules* from the Environment Window Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *CRRESPRO* in the *Available Science Modules* list. A CRRESPRO object will be added to the *Active Science Modules* list and a set of CRRESPRO Options will appear in the Environment Window.

- From the *Energy Channel* list select the 47.0 MeV channel.
- Click on the *B-Model* button and select the *IGRF95* option to generate a realistically positioned South Atlantic Anomaly (SAA) for Low Earth Orbit (LEO) altitudes relatively quickly. Note that the IGRF95 internal plus Olson-Pfitzer external models (*IGRF95/O-P*) were used to construct CRRESPRO but take considerably longer to run and that while the offset-tilted dipole option *Dip-Tilt-Off* is fastest, it does not yield a realistically positioned SAA.
- Click on the *Activity* button and select the *Quiet* model option. The *Quiet* model contains only the primary inner belt and is more typical of the inner magnetosphere. The *Active* model was constructed from CRRES data following the 24 March 1991 magnetic storm and contains the second proton belt.
- Click on the *Grid Tool* button at the bottom of the window and the Grid Setup Window will appear.
- At the top of the Grid Setup Window there are options for grid spacing, grid geometry, and coordinate system. Use the defaults, which will generate a linearly spaced spherical grid defined by radius, geocentric latitude, and geocentric longitude. Set “Npoints” equal to 40 for “Rad, GEOC (Re)”, 40 for “Lat, GEOC (Deg N)”, and 40 for “Lon, GEOC (Deg E)”. Set the minimum and maximum radius to 1.0 and 3.0 Re (Earth radii), respectively. Use the defaults for the latitude range (-68° to +68°) and the longitude range (-180° to +180°). Close the Grid Setup Window by clicking the *Apply* button at the bottom of the window. After the Wait Window closes, the *Model Status* box will give the message that the grid has changed and the model must be rerun.
- Click on the *Run Model* button at the bottom of the Environment Window. A red Wait Window will appear while CRRESPRO is running. When the model is complete the Wait Window will disappear and the identification and status of the model will appear in the *Model Status* box in the lower part of the window.

3) Create a CRRESELE Science Module (outer electron radiation belt) data set,

- Click on *CRRESELE* in the *Available Science Modules* list. A CRRESELE object will be added to the *Active Science Modules* list and a set of CRRESELE Options will appear in the Environment Window.
- From the *Energy Channel* list select the 1.6 MeV channel.
- Click on the *B-Model* button and select the *IGRF85* model as was done for CRRESPRO.
- From the *Ap15 Model Range* list, choose *Ap15 7.5 - 10.0* to approximate the global value of 7.6 (shown below the *Compute* button) which was determined for day 200/1997. This will select a model constructed from CRRES data during those time intervals when the average value of daily Ap over the preceding 15 days was between 7.5 and 10.
- Click on the *Grid Tool* button at the bottom of the Environment Window and the Grid Setup

Window will appear. Set “Npoints” equal to 60 for “Rad, GEOC (Re)”, 60 for “Lat, GEOC (Deg N)”, and 40 for “Lon, GEOC (Deg E)”. Set the grid settings to a radius range of $r = 1.0$ to $7.0 R_E$, a latitude range of -85° to 75° , and a longitude range of -180° to 180° . Close the Grid Setup Window by clicking the *Apply* button at the bottom of the window. A Wait Window appears while the grid is generated.

- Click on the *Run Model* button at the bottom of the window. A Wait Window will appear while CRRESELE is running. When the model is complete the Wait Window will disappear and the identification and status of the model will appear in the *Model Status* box in the lower part of the window.

4) Create an AURORA Science Module data set,

- Click on *AURORA* in the *Available Science Modules* list. An AURORA object will be added to the *Active Science Modules* list and a set of AURORA Options will appear in the bottom of the Environment Window.
- Leave the “Generate” and the “External B-Field” options at their default values. Set “Internal B-Field” to the *Fast IGRF* option. There are two auroral *Model* options, one which is parameterized by Kp (*KP*) and one by interplanetary magnetic field and solar wind speed (*IMF/SW*). Use the default *KP* option.
- Click on the *Grid Tool* button at the bottom of the window. The default is a two-dimensional latitude-longitude grid at a constant radius of 1.0173 Earth radii. This is the original domain on which the aurora model was constructed. Set the radius minimum (“Min”) and maximum (“Max”) to 1.1318 R_E to agree with the DMSP altitude of 840 km. Set “Npoints” equal to 80 for “Lat, GEOC (Deg N)” and “Lon, GEOC (Deg E)”. Close the Grid Setup Window by clicking on the *Apply* button.
- Click on the *Run Model* button at the bottom of the Environment Window. The *Model Status* box will indicate that the Global Parameters “Day”, “Time”, and “Kp” are being used to construct the model. When the model is complete the Wait Window will disappear and the *Model Status* box will be updated.

5) Create the DMSP orbit data set,

- Return to the Menu Bar of the Environment Window, click on *Modules* and select *Applications*. *Available Application Modules* and *Active Application Modules* lists will appear.
- Scroll down the *Available Application Modules* list and select *SATEL-APP* (satellite application). A SATEL-APP object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Click on the *Select File* button and a pop-up window will appear with a *Build list from file:* scroll box. Enter “\$AFGS_HOME/PLGS/examples/elements/*” in the “Filter” text window and click on the *Filter* button at the bottom of the window. Scroll down the *Build list from file* list and select the file “dmSP.txt”. Click on the *OK* button in the lower left corner.

- A list of DMSP satellites will appear in the *Current Element File* list in the middle of the window. Select *DMSP F14* and a pop-up window will appear listing the orbit elements for DMSP F14. Close the window using the menu bar in the upper left corner. The satellite name and the reference time associated with the orbital elements are given in boxes below the list box. The default value for the start time (“T_start”) is taken from the global values at the top of the Environment Window. A 1 day interval with a 60 second time step are set by default.
- Edit the “T_start” text box to read “07/19/97 8:30:00” and edit the “T_stop” text box to read “07/19/97 12:30:00”. Click the *Run Model* button to create the orbit data set. When completed, the *Model Status* box will indicate that the “MODEL IS READY AND UP TO DATE.”

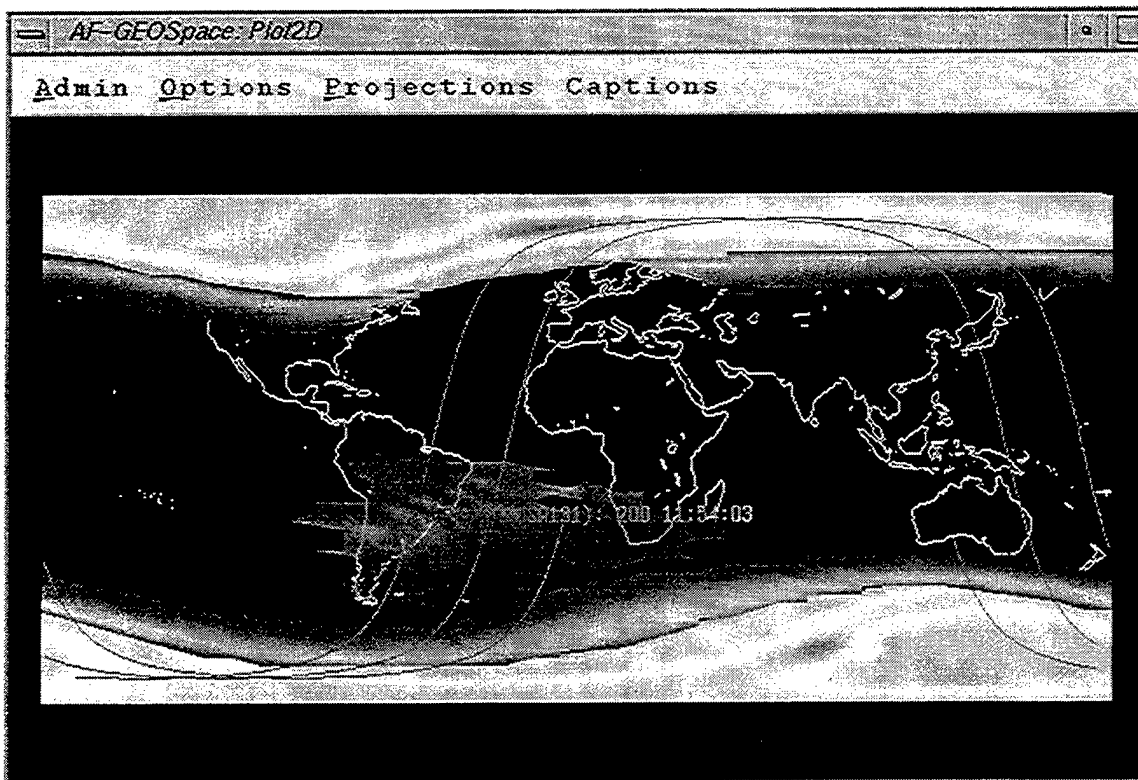
6) Create 2D and 3D views of Earth with an orbit trace,

- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window will appear for displaying 3D gridded data sets.
- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 2D Plot*. A Plot2D Window will appear for displaying 2D gridded data sets.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of EARTH Options will appear in the bottom of the Environment Window.
- Leave the “Outline Detail” at the default setting of *Geographic Bndys*. The less detail shown on the Earth, the faster the response for its 3D manipulation.
- Click on *PLOT3D* in the *Display In* list at the bottom of the window and a globe will appear in the Plot3D Window. To simultaneously display both 2D and 3D Earth, hold the shift button down on the keyboard while clicking on the *PLOT2D* in the *Display In* list. A two-dimensional map of the Earth will appear in the Plot2D Window. The color bar in each window may be toggled on/off by using the *Options* menu at the top bar of the Plot3D Window and clicking on *Show Color Bar*. Now turn off each color bar to make room in the windows.
- Scroll down the *Available Graphics Modules* list and select *SATELLITE*. A SATELLITE object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Click the *Orbit* button and select *DMSP F14*. Select both *PLOT2D* and *PLOT3D* in the *Display In* list. The DMSP orbit (in the geocentric reference frame) will appear in the Plot2D and Plot3D Windows. Click on the *Label* button and select the *Rad, Lat, Lon* option. Radius (1.13 Re), latitude (-81.14°), and longitude (240.06°) will be displayed at the current satellite position (solid red circle). Click the *Label* button and select *Time*. The coordinate label will be replaced by the day of year/time. The default position of the satellite corresponds to a time $T = T_{\text{start}} + 0.5 \cdot (T_{\text{stop}} - T_{\text{start}})$ which is approximately 10:30:00 (of day 200).

- The *Satellite position (%)* slider (default setting of 0.5) may be used to move the satellite along its orbit. Moving the slider to 0.865 will position DMSP14 over the South Atlantic Anomaly (SAA) at “r”=1.14, “lat”=-29.89°, “lon”=304.49°. For fine adjustment, use the left/right *Step* arrows located just below the *Satellite position (%)* slider (or use the left/right keyboard arrows while the cursor is on the slider).
- 7) Create 2D view of the inner proton radiation belt, the outer electron radiation belt, and the auroral oval,
- Scroll up the *Available Graphics Modules* list and select *COORD-SLICE*. A *COORD-SLICE* object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
 - The coordinate parameters *C0*, *C1*, and *C2* correspond to the three coordinates that are set by the Grid Tool in the appropriate Science Module (for this example they represent geocentric radius, latitude, and longitude). Use the default setting (*C0*) to produce a slice of flux values at constant radius. Click the *Data* button and select *Flux* under the *CRRESPRO* option. Click on the window background to register your choice. Select the *PLOT2D* line in the *Display In* list at the bottom of the Environment Window and the proton flux data will appear.
 - Click on the satellite *Position Value* slider button to display the value of the selected coordinate - in this case, as both radius (“Rad”) and altitude (“Alt”). By default, the radial position is set at 2.00 Re. A solid blue band continuous in longitude appears which represents the intensity of CRRESPRO model flux at this altitude. Adjust the slider button to the DMSP orbit altitude (~843 km) or radius (1.132 Re). Use the left/right arrows for fine adjustment if necessary. At DMSP altitude the inner belt appears as a relatively localized area centered near 304° E longitude and -30° latitude.
 - The transparency of the CRRESPRO Coordinate Slice can be changed by clicking on the *Transp.* button at the far right of the Coordslice Options section. A *Transparency Parameters* section will be displayed at the bottom of the window. Changing the *Alpha Value* to a smaller number using the slider increases the transparency. A value of 0.70 is reasonable for this example. At this altitude, it should be apparent that a maximum in flux intensity appears near the east coast of South America. This feature is referred to as the South Atlantic Anomaly (SAA). Click on the *Windows* button (not at the top, but at the right hand side of the Environment Window) to retrieve the window display list.
 - Return to the *Available Graphics Modules* list and click twice on *COORD-SLICE* (one click to remove the highlighting, a second click to activate a new graphics object). A second *COORD-SLICE* object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
 - Click the *Data* button and select *Flux* under the *CRRESELE* option. Click anywhere on the window to register your choice. Select the *PLOT2D* line in the *Display In* list at the bottom of the window. A constant radius slice of the CRRESELE model electron flux will appear in the Plot2D Window. Click on the *Position Value* slider and the default value of “Rad”=4.0 Re will appear below the slider. Slide to position 0.022 (“Rad”=1.132 Re). You may need to use the

keyboard left/right arrow keys for fine position adjustment. These regions represent the low altitude projection (the “horns”) of the outer belts. As with the SAA, the gap in the electron belt at this altitude over the North Atlantic is due to the magnetic dipole offset and complicated multi-pole character of the Earth’s internal magnetic field.

- Return to the *Available Graphics Modules* list and click twice on *COORD-SLICE*. A third COORD-SLICE object will be added to the *Active Graphics Modules* list and a set of Coord-slice Options will appear in the Environment Window.
- Click the *Data* button and select the *Ion Number Flux* under the *AURORA* option. Click anywhere on the window background to register your choice. Select the *PLOT2D* line in the *Display In* list at the bottom of the window. A 2D coordinate slice of the ion auroral oval flux at a constant radius will appear in the Plot2D Window in both hemispheres. The image in the 2D Window should resemble the following figure.



8) Create 3D view of the inner proton radiation belt, the outer electron radiation belt, and the auroral oval,

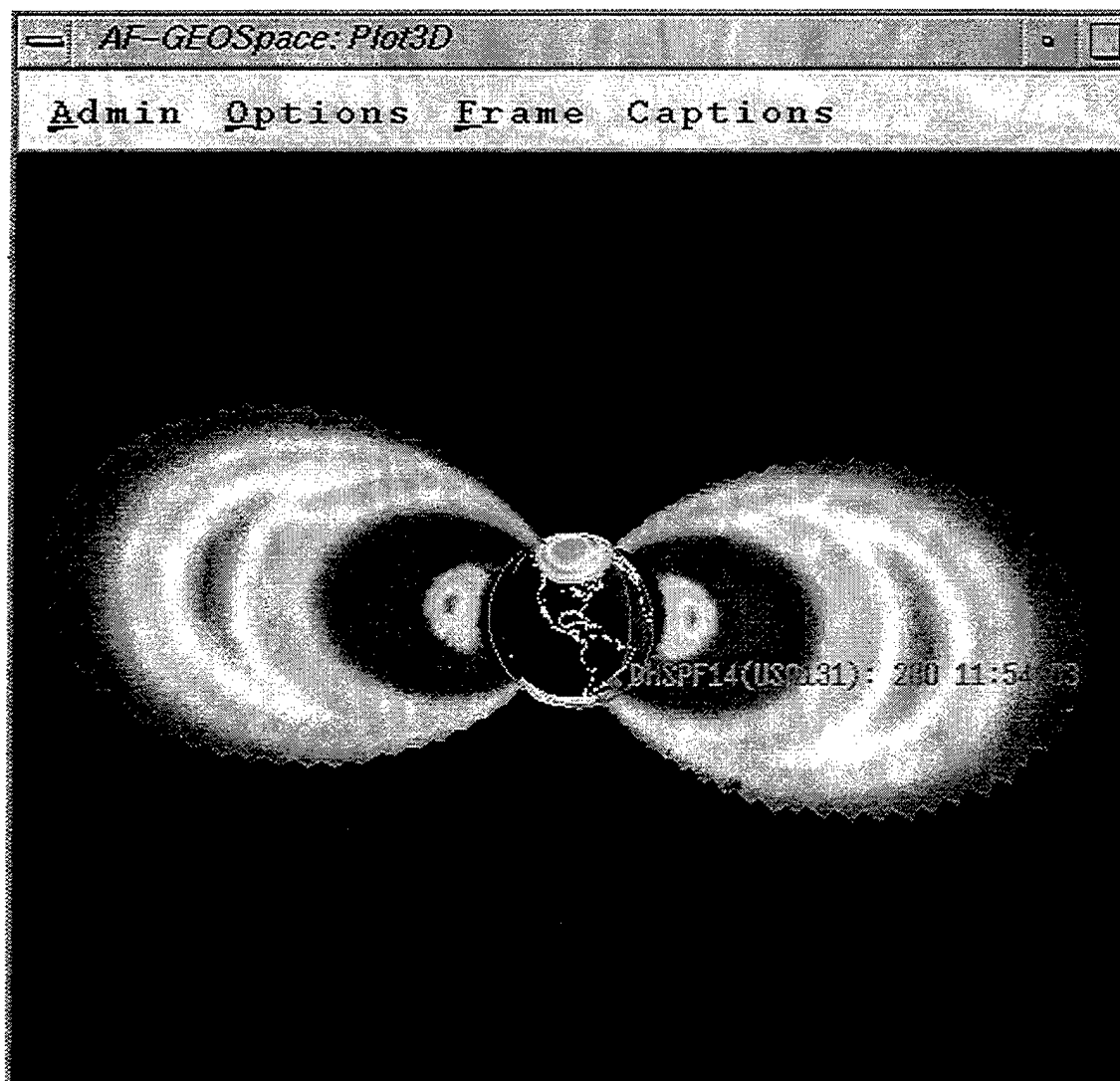
- Return to *Available Graphics Modules* and click twice on *COORD-SLICE*. A fourth COORD-SLICE Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select *Flux* under the *CRRESPRO* option. Click anywhere on the window background to register your choice. Under “Coordinate”, select the *C2* option.

- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A two-dimensional coordinate slice of the CRRESPRO model proton flux at a constant longitude will appear in the Plot3D Window. You may need to rotate the Earth to see the coordinate slice.
- Return to *Available Graphics Modules* and click twice on *COORD-SLICE*. A fifth COORD-SLICE Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select the *Flux* under the *CRRESELE* option. Click anywhere on the window to close the Data box. Under “Coordinate” select the *C2* option.
- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A cross-section of the outer electron belt from the CRRESELE model appears in the Plot3D Window.
- Repeat the first 6 steps in Section 8 to generate a second cross-section of the inner proton and outer electron belts. In each of these two new cross-sections, move the *Position Value* slider under Coordslice Options to ~ 1.0 so that the longitude slice is diametrically opposed (at 180°) to the two original cross-sections.
- Finally, include a 3D image of the auroral oval. Return to *Available Graphics Modules* and click twice on *COORD-SLICE*. An eighth COORD-SLICE Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select the *Ion Number Flux* under the *AURORA* option. Click anywhere on the window background to register your choice. Leave the “Coordinate” set at *C0*.
- Select the *PLOT3D* line in the *Display In* list at the bottom of the window.
- The image in the Plot3D Window can be rotated/scaled by using the left/center mouse button when the pointer is in the Plot3D Window. Alternatively, use the *Admin* item on the Menu Bar of the Plot3D Window and select the *Show View* option. The options provided in the *Show View* panel allow for rotation, scaling, and translation. Use these options to set the *Latitude* slider to 23.6, *Longitude* to 273.2, *Twist* to 0.8, *Scale* to 1.16, and *Zoom* to 0.96. Close the Viewer Window. The Plot3D Window should now resemble the figure on the next page.

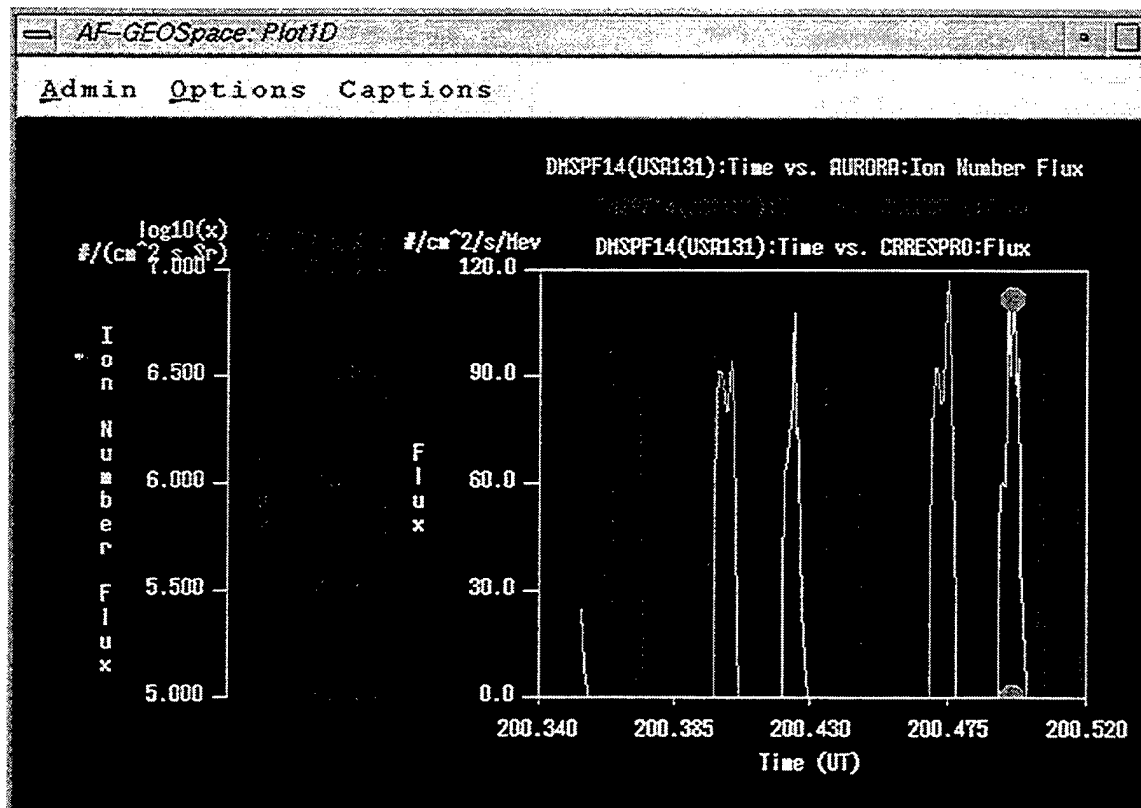
9) A one-dimensional plot of the CRRESPRO proton flux, CRRESELE electron flux, and AURORA ion number flux as seen by the DMSP satellite can be generated as follows,

- Return to the Menu Bar of the Environment Window, pull down *Windows* and select *Create 1D Plot*. A Plot1D Window will appear.
- Scroll down the *Available Graphics Modules* list and select *ORBIT-PROBE*. An ORBIT-PROBE Object will be added to the *Active Graphics Modules* list and a set of Orbit Probe Options will appear in the Environment Window.
- Click on the *Path/Abscissa* button and select the *Time* option under *DMSP F14*. Then click on the *Data/Ordinate* button and select the *Flux* option under *CRRESPRO*.

- Select the *PLOT1D* line in the *Display In* list at the bottom of the window. A plot of CRRESPRO Flux vs. Time along the DMSP orbit will appear in the Plot1D Window.
- Repeat the last 3 steps, replacing CRRESELE for CRRESPRO. Now, repeat those same 3 steps once again but replace AURORA for CRRESPRO



- Since the time scale (x-axis) is the same for all three flux curves, two of the three may be deleted to avoid redundancy. To do this, click on the *Options* button under the current ORBIT-PROBE Window and a *Line Plot Parameters* Window will appear. Click on the *On* button next to the x-axis to toggle it to the *Off* position. Now activate a second ORBIT-PROBE Window by selecting another ORBIT-PROBE object under the *Active Graphics Modules* list (not Available list!). Repeat the above procedure using the *Options* button, deleting a second x-axis. The Plot1D Window should resemble the following figure.



This 1D figure and the 2D figure produced earlier illustrate how DMSP can be exposed, in turn, to auroral (green), proton belt (white), and electron belt (blue) fluxes.

This completes the Example of the Low Earth Orbit Particle Environment.

3) Low Earth Orbit Total Dose

The following example demonstrates the use of the APEXRAD Science and Application Modules, the Satellite Application Module (SATEL-APP), and a variety of visualization tools.

Goal: View the total radiation dose distribution encountered by the low Earth orbit Defense Meteorological Satellite Program (DMSP) satellite. Contributions are from the South Atlantic Anomaly (SAA) where unusually high fluxes of inner zone particles (predominantly protons) are encountered due to the asymmetry of the Earth's magnetic field, and from the high latitude / low altitude projection of the outer radiation belt MeV electron population. (See Example 2 for an illustration of the individual electron and proton populations impacting the low Earth orbit particle environment)

Procedure Summary: Section 1 starts a Static Model session, Section 2 generates the APEXRAD dose environment data sets, Section 3 generates the DMSP orbit data sets, Section 4 creates a 3D view of the dose environment, Section 5 creates a 1D dose vs. time plot along with an animation, and Section 6 runs the APEXRAD application with the DMSP orbit and generates a text output window with predicted annual doses.

1) Start a GEOSpace session and set global input parameters,

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* modules will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Edit the *Globals* text boxes for the year (1997), day of year (200), and time (08:30). This date is consistent with the reference time of the orbit elements to be used, and will help when it is time to run the animation. Click on the *Archive* option of the *Globals* button and the Kp, SSN, F10.7, and Ap values appropriate for this time appear (although they will not be used in this example).

2) Create APEXRAD Science Module data set,

- Choose *Modules* from the Menu Bar and select *Science* from the options and *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *APEXRAD* in the *Available Science Modules* list. An APEXRAD object will be added to the *Active Science Modules* list and a set of APEXRAD Options will appear in the Environment Window.
- Click on the *B-Model* button and select the *IGRF95* option to generate a realistically positioned South Atlantic Anomaly (SAA) for Low Earth Orbit (LEO) altitudes relatively quickly. Note that the IGRF95 internal plus Olson-Pfitzer external models (*IGRF95/O-P*) were used to construct CRRESPRO but take considerably longer to run and that while the offset-tilted dipole option *Dip-Tilt-Off* is fastest, it does not yield a realistically positioned SAA.

- Use the *Shielding* button to select *232.5 mil Al*, corresponding to the shielding thickness of the hemispheric dome number 3 of the APEX satellite.
- Leave the *Channel* button set at the default called *Total* which represents the sum of the High LET (Linear Energy Transfer) and Low LET dose channels.
- Click on the *Activity* button to see that there are a number of activity ranges (parameterized by the 15 day average Ap index) represented, plus an average activity level for the whole mission. Select the *Whole Mission* model (default).
- Click on the *Grid Tool* button and the Grid Setup Window will appear. At the top of the Grid Setup Window there are options for grid spacing, grid geometry, and coordinate system. Use the defaults, which will generate a linearly spaced spherical grid defined by radius (“Rad, GEOC (Re)”), geocentric latitude (“Lat, GEOC (Deg N)”), and geocentric longitude (“Lon, GEOC (Deg E)”). Set “Npoints” equal to 40 for radius, 60 for latitude, and 60 for longitude. Set the minimum and maximum radius to 1.0 and 3.0 Earth radii, respectively. Adjust the latitude range to go from -70° to +70° and use the longitude range defaults (-180° to +180°). Click the *Apply* button at the bottom of the window to generate the grid and close the Grid Setup Window. A Wait Window will appear while the grid is being set up.
- Click on the *Run Model* button at the bottom of the window. A red Wait Window will appear while APEXRAD runs (for several minutes). When the model is complete the Wait Window will disappear and the identification and status of the model will appear in the *Model Status* box in the lower part of the Environment Window.

3) Create the DMSP orbit data set,

- Return to the Menu Bar at the top of the window, click on *Modules* and select *Applications*. *Available Application Modules* and *Active Application Modules* lists will appear.
- Scroll down the *Available Application Modules* list and select *SATEL-APP* (satellite application). A SATEL-APP object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Click on the *Select File* button and a pop-up window will appear with a *Build list from file:* scroll box. Enter “\$AFGS_HOME/PLGS/examples/elements/*” in the “Filter” text field and click on the *Filter* button. Scroll down and select the file “dmsp.txt”. Click on the *OK* button in the lower left corner.
- A *Current Element File* list of satellites with orbit elements available will appear in the middle of the window. Scroll down this list and select *DMSPF14*. A pop-up window will appear listing the orbit elements for DMSPF14. Close the window using the menu bar in the upper left corner. The reference time for the orbital elements is given in the scroll box, and is also displayed below the scroll box as T_ref (01/11/99, 03:43:39), along with T_start and T_stop.
- Edit the “T_start” text box to read “07/19/97 8:30:00” and edit the “T_stop” text box to read “07/19/97 15:30:00”. Click the *Run Model* button to create the orbit data set. When complete,

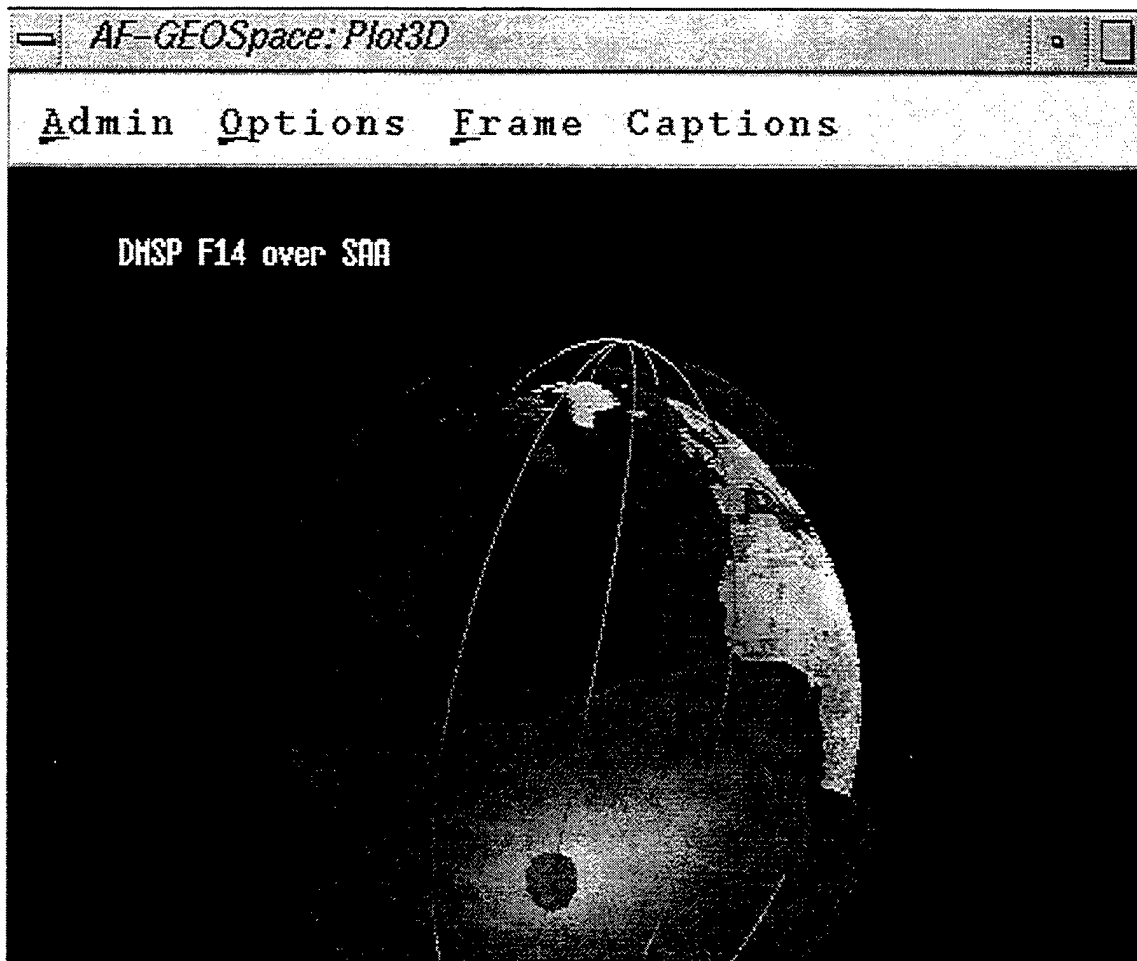
the *Model Status* box will indicate that the “MODEL IS READY AND UP TO DATE.”

4) Create 3D plot,

- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window will appear for displaying 3D gridded data sets.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of EARTH Options will appear in the bottom of the Environment Window.
- Leave the “Outline Detail” at the default setting of *Geographic Bndys*. The less detail shown on the Earth, the faster the response for its 3D manipulation.
- Click on *PLOT3D* in the *Display In* list at the bottom of the window and a globe will appear in the Plot3D Window. The color bar may be toggled on/off by using the *Options* menu at the top bar of the Plot3D Window and clicking on *Show Color Bar*. Turn the color bar off and the globe will expand to fill out more of the window.
- The globe in the Plot3D Window can be rotated (or scaled) by using the left (or center) mouse button when the pointer is in the Plot3d Window. Alternatively, the 3D image may be manipulated by going to the *Admin* menu at the top of the Plot3D Window and selecting the *Show View* option. A View Window with many different options will appear.
- Scroll down the *Available Graphics Modules* list and select *SATELLITE*. A SATELLITE object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Click the *Orbit* button and select *DMSPF14*, then click the *Label* button and select the option *Time*.
- Select *PLOT3D* in the *Display In* list. The DMSP orbit (in the geocentric reference frame) will appear in the Plot3D Window with the satellite name and date/time shown next to the satellite marker (solid red circle). The default position of the satellite corresponds to a time $T = T_{\text{start}} + 0.5 \cdot (T_{\text{stop}} - T_{\text{start}})$. Change the satellite position to where the center of the SAA is located by clicking on and moving the *Satellite position (%)* slider until its relative position reads 0.489. The satellite/time label in the Plot3D Window should give the day/time as 200 11:54. Fine adjustment may be accomplished using the keyboard left/right arrows. Set the *Label* button to *Off*.
- Return to the *Available Graphics Modules* list and select *COORD-SLICE*. A COORD-SLICE Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select *Dose* under the *APEXDOSE* option. Click anywhere on the

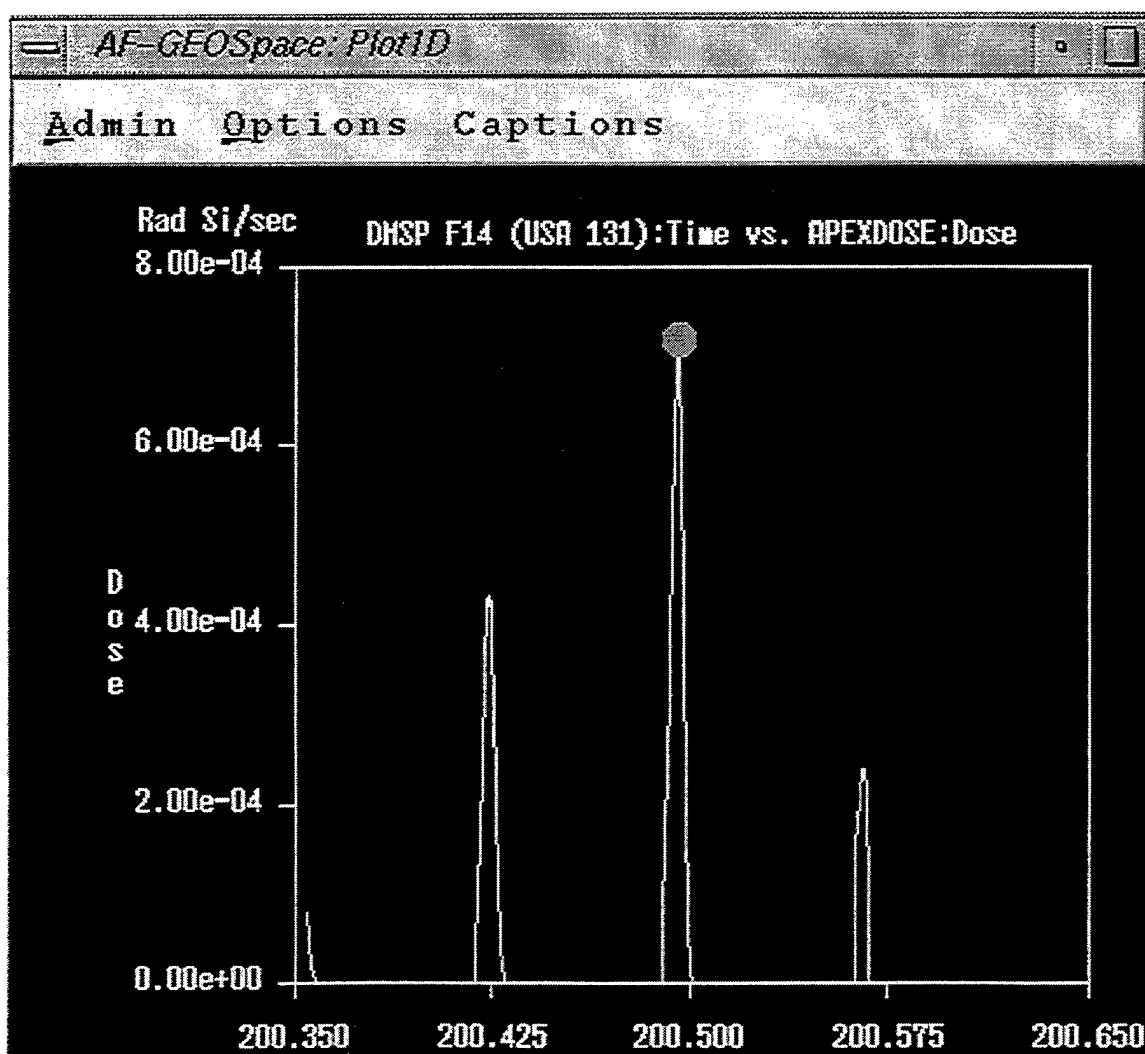
window to close the Data box. Click on the *Orbit* button and select *DMSPF14*. This will tie the altitude of the dose contour to the orbit altitude. The coordinate parameters *C0*, *C1*, and *C2* correspond to the first, second, and third coordinates, respectively, which are set by the Grid Tool in the appropriate Science Module (for APEXRAD they are radius, geographic latitude, and geographic longitude). Under “Coordinate” select the *C0* option to get a radial slice (specified by orbit radius).

- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A surface of the APEXRAD model dose at a fixed radius will appear in the Plot3D Window.
- To include a caption in the plot, pull down the *Captions* menu at the top of the Plot3D Window and select *Show Captions*. Pull down the *Captions* menu again and select *Caption Text*. In the pop-up window, enter the text “DMSP F14 over SAA” into the “Caption 1” text box (use the default x and y caption position coordinates). Click *Update* and then close the window.
- Using the *Admin* menu at the top of the Plot3D Window, select the *Show View* option and a View Window will appear. Set the *Latitude* slider to 2.0, *Longitude* to 310.0, *Twist* to 0.0, *Scale* to 4.0, and *Zoom* to 1.0. Close the View Window. The Plot3D Window should resemble the following figure.



5) Generate a one-dimensional plot of the APEXRAD dose as seen by the DMSP satellite,

- Return to the Menu Bar of the Environment Window, pull down *Windows* and select *Create 1D Plot*. A Plot1D Window will appear.
- Return to the *Available Graphics Modules* list and select *ORBIT-PROBE*. An ORBIT-PROBE Object will be added to the *Active Graphics Modules* list and a set of Orbit Probe Options will appear in the Environment Window.
- Click on the *Path/Abscissa* button and select *Time* under the *DMSP* option. Then click on the *Data/Ordinate* button and select *Dose* under the *APEXRAD* option.
- Select *PLOT1D* in the *Display In* list at the bottom of the window. A plot of APEXRAD Dose vs. Time along the DMSP orbit will appear in the Plot1D Window.
- Move the *Satellite position (%)* slider to read .489 (day ~200.5). The Plot1D Window should resemble the following figure.



- To animate the satellite motion simultaneously in both windows, pull down *Windows* from the Menu Bar of the Environment Window and select *Animation*. A pop-up window will appear giving animation options. Click on the *Find Range* button to automatically load the “T_start” and “T_stop” times from the available SATELLITE objects. Reset “T_start” to 200.350 and “T_stop” to 200.575 to be within the time range of the 1D plot. Click on the *Start/Continue* button to begin the animation. The red satellite markers in both the 3D and 1D plots should step along (in 300 second steps) in phase with each other as the satellite periodically encounters peak flux in the SAA. Remember that the APEX data in the Plot3D Window is set to track the satellite’s altitude.

6) Run the APEXRAD Application Module to determine approximate annual doses for the specified DMSP orbit,

- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Click on *APEXRAD-APP* in the *Available Application Modules* list. An *APEXRAD-APP* object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Specify an orbit by clicking on the *Select File* button. A *Build list from file:* scroll box will be displayed. Scroll down to select *dmisp.txt* and then click the *OK* button. A *Current Element File* list is generated. Click on *DMSPF14* and a pop-up window will appear with DMSPF14 orbit elements. Close the pop-up window. We will use the default “T_start” time (07/19/97 08:30) and “T_stop” time (07/20/97 08:30).
- Click the *Run Model* button at the bottom. A scrolling text window will pop-up with orbit averaged dose, normalized to 1 year, for the various channels and model activities. The text window is two full pages long and will not be reproduced here.

This completes the Example of the Low Earth Orbit Total Dose.

4) Single Event Upset Environment

The following example demonstrates the use of the CRRES Heavy Ion Model Environment (CHIME) and CRRESPRO Science Modules, the Linear Energy Transfer Application Module (LET-APP), the Satellite Application Module (SATEL-APP), and a variety of visualization tools.

Goal: Galactic Cosmic Rays (GCR), Anomalous Component cosmic rays (AC), Solar Energetic Particles (SEP), and trapped proton radiation belt particles are each capable of producing damaging single-particle radiation effects in microelectronic devices resulting in what are called Single Event Upsets (SEU). The goal of this example is to demonstrate the use of the CHIME and CRRESPRO Science modules to create a three dimensional view of the SEU producing environment and a one dimension temporal plot of the fluxes encountered in that environment by select satellites. The LET-APP Application module will also be used to produce Linear Energy Transfer (LET) spectra appropriate to the orbits.

Procedure Summary: This is a fairly extensive example which involves creating two distinct SEU environments (low and high SEU rates) in which both a Low Earth Orbit (LEO) and a Geosynchronous Orbit (GEO) satellite are simulated. The low SEU environment is first modeled: Section 1 starts a Static Model session, Sections 2-3 generate the SEU environment data sets, Sections 4-5 generate the LEO and GEO orbit data sets, Section 6 creates a 3D view of the environment, Section 7 creates a 1D plot of LEO and GEO fluxes, and Sections 8-9 run the LET-APP application for LEO and GEO satellites and display the resulting LET spectra. Section 10 then suggests repeating this whole procedure (Sections 1-9), making the appropriate changes from a low to a high SEU environment. For the first and second passes through Sections 1-9, follow the options for a low and high SEU environment, respectively.

1) Start a GEOSpace session,

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* modules will be added to the *Active Environment Modules* list and the Environment Window will appear. Leave the date, time, and global environment variables a default values.

2) Create a CHIME Science Module (cosmic ray and solar particle) data set,

- Choose *Modules* from the Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *CHIME* in the *Available Science Modules* list. A CHIME object will be added to the *Active Science Modules* list and a set of CRRES Heavy Ion Model Environment (CHIME) Options will appear in the Environment Window.
- Under "Specify Environment":
 - Click on the *Flux Inputs* button and select the *Period* option. This allows you to enter a specific time period for which the CHIME program will determine an appropriate heavy ion flux

level. Specify the beginning and end year/day by editing the text fields “Year 1”, “Day 1”, “Year 2”, and “Day 2”. Remember that you should choose either the low or high SEU environment consistently throughout Sections 1-9. Start off with the low SEU environment (~solar maximum), by entering the following: “Year 1”=2004, “Day 1”=1, “Year 2”=2004, “Day 2”=2. For the high SEU environment (~solar minimum), enter the following: “Year 1”=1998, “Day 1”=1, “Year 2”=1998, “Day 2”=2.

- Click on the *Solar Events* button. For the low SEU environment select *Off* to specify no Solar Events (default setting). For the high SEU environment, select the *June 91 Peak* option to characterize the solar event environment using the peak fluxes recorded by the CRRES satellite during the June 1991 solar event.

- Under “Galactic cosmic rays (GCR) and solar energetic particles (SEP)”:
 - Set the “Atomic Z (1-28):” minimum to 1 and maximum to 1. This will reduce run time; more accurate results require inclusion of heavier elements.
 - Set the “Energy (MeV/n):” minimum to 10 and maximum to 50,000. (default)
- Under “Anomalous Component of Cosmic Ray Particles (AC)”:
 - Set the “Mass(4-20):” minimum to 4 and maximum to 4. This will reduce run time; more accurate results require inclusion of heavier elements.
 - Set the “Energy (MeV/n):” minimum to 10 and maximum to 2050. (default)
 - Set the *Flux units:* button to *CRRESPRO: #/(cm^2 s Mev/n)* to facilitate comparison with CRRESPRO Science Module output from the next section.
- Click on the *Grid Tool* button and a Grid Setup Window will appear. Change the “Rad, GEOC (Re)” settings to the following: “Npoints” = 4, “Min” = 1.0, “Max” = 7.0. Leave all other grid parameters at their default values. Close the window by clicking the *Apply* button. A Wait Window will appear while the grid is generated.
- Click on the *Run Model* button at the bottom of the Environment Window. A Wait Window will appear while CHIME is running. When the model is complete the Wait Window will disappear and the status of the model will appear in the *Model Status* box in the lower part of the Environment Window.

3) Create CRRESPRO Science Module (inner proton radiation belt) data set,

- Click on *CRRESPRO* in the *Available Science Modules* list. A CRRESPRO object will be added to the *Active Science Modules* list and a set of CRRESPRO Options will appear in the Environment Window.
- From the *Energy Channel* list select the 47.0 MeV channel.
- Click on the *B-Model* button and select the *IGRF95* option to generate a realistically positioned South Atlantic Anomaly (SAA) for Low Earth Orbit (LEO) altitudes relatively quickly. Note that the IGRF95 internal plus Olson-Pfitzer external models (*IGRF95/O-P*) were used to construct CRRESPRO but take considerably longer to run and that while the offset-tilted dipole option *Dip-Tilt-Off* is fastest, it does not yield a realistically positioned SAA.

- Click on the *Activity* button to select the appropriate inner proton activity level. For the low SEU environment select the *Quiet* model (default setting) which contains only the primary inner belt and was constructed with data from the first eight months of CRRES data preceding the great March 1991 storm. For the high SEU environment select the *Active* model which was constructed from CRRES data from the time following the 24 March 1991 magnetic storm and includes the secondary as well as primary proton belt.
- Click on the *Grid Tool* button at the bottom of the Environment Window and the Grid Setup Window will appear. At the top of the Grid Setup Window there are options for grid spacing, grid geometry, and coordinate system. Use the defaults, which will generate a linearly spaced spherical grid defined by radius, geocentric latitude, and geocentric longitude. Set “Npoints” equal to 40 for “Rad, GEOC (Re)”, 40 for “Lat, GEOC (Deg N)”, and 40 for “Lon, GEOC (Deg E)”. Set the minimum and maximum radius to 1.0 and 3.0 Re (Earth radii), respectively. Use the default latitude range (-68° to +68°) and the longitude range (-180° to +180°). Close the Grid Setup Window by clicking the *Apply* button. A Wait Window appears temporarily.
- Click on the *Run Model* button at the bottom of the Environment Window. A Wait Window will appear while CRRESPRO is running.
- When the model is complete the Wait Window will disappear and the identification and status of the model will appear in the *Model Status* box in the lower part of the window.

4) Create a Low Earth Orbit (LEO) data set using the APEX ephemeris,

- From the Menu Bar at the top of the Environment Window, click on *Modules* and select *Applications*. *Available Application Modules* and *Active Application Modules* lists will appear.
- Scroll down the *Available Application Modules* list and select *SATEL-APP* (satellite application). A SATEL-APP object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Click on the *Select File* button and a pop-up window will appear with a *Build list from file list*. Enter “\$AFGS_HOME/PLGS/examples/elements/*” in the “Filter” text window and click on the *Filter* button in the lower part of the window. Select *APEX_94221.ELE* from the *Build list from file list* and click the *OK* button.
- From the *Current Element File* list that appears in the middle of the Environment Window select *APEX*. A pop-up window will appear listing APEX orbit elements. Close the window using the upper left corner of the menu bar. The *Current Element File* reference date associated with APEX (“T_ref”=08/09/94) also appears in a text box below.
- Edit the “T_start” text box to read “01/01/94 18:00:00” and edit the “T_stop” text box to read “01/02/94 02:00:00”. Click the *Run Model* button and when the orbit is generated, the message in the *Model Status* box is updated to read “MODEL IS READY AND UP TO DATE.” Note that the orbit propagator works best when the start and stop times are close to the reference time. Since the orbit time interval has no effect on the model environments, the same time interval will be used for both the Low and High SEU environment.

5) Create a Geosynchronous Orbit (GEO) data set using the GOES-8 ephemeris,

- Click twice on *SATEL-APP* in the *Available Application Modules* list. A second *SATEL-APP* object will be added to the *Active Application Modules* list and a set of Ephemeris Data options will appear in the Environment Window.
- Click on the *Select File* button and a pop-up window will appear with a *Build list from file* list. Enter “\$AFGS_HOME/PLGS/examples/elements/*” in the “Filter” text window and click on the *Filter* button in the lower part of the window. From the *Build list from file* list select *goes94.txt* and click the *OK* button in the lower left corner.
- From the *Current Element File* list that appears in the middle of the window select *GOES 8*. A pop-up window will appear listing GOES 8 orbit elements. Close the window using the menu bar in the upper left corner. The *Current Element File* reference date associated with GOES8 (T_ref=01/01/94) also appears in a text box below.
- Edit the “T_start” text box to read “01/01/94 18:00:00” and edit the “T_stop” text box to read “01/02/94 02:00:00”. Click the *Run Model* button to create the *SATEL-APP* data set. When complete the *Model Status* box is updated to read “MODEL IS READY AND UP TO DATE.”

6) Examine the three dimensional distribution of the inner radiation belt protons, solar particles, and cosmic ray populations representing the low (or high) SEU producing environment.

- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window will appear for displaying 3D gridded data sets.

Display Earth and Orbit Traces

- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* list will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An *EARTH* object will be added to the *Active Graphics Modules* list and a set of *EARTH* Options will appear in the bottom of the Environment Window.
- Under “Outline Detail” leave the default setting of *Geographic Bndys*. The less detail shown on the Earth, the faster the response for its 3D manipulation.
- Click on *PLOT3D* in the *Display In* list and a globe will appear in the Plot3D Window.
- Scroll down the *Available Graphics Modules* list and select *SATELLITE*. A *SATELLITE* object will be added to the *Active Graphics Modules* list and a set of *Satellite Options* will appear in the Environment Window.
- Under “Satellite Options”, click the *Orbit* button and select *APEX*, then click the *Label* button and choose *Time*. Select *PLOT3D* in the *Display In* list. The *APEX* orbit (in the geocentric reference frame) will appear in the Plot3D Window with the name and time shown next to the satellite marker (solid red circle).

- Slide the *Satellite position (%)* slider to .707 to place APEX above the SAA (day of year/time should read 001 23:37:00). The “step” arrows can be used for finer adjustment of the slider.
- Return to the *Available Graphics Modules* list and click twice on *SATELLITE*. A second *SATELLITE* object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Click the *Orbit* button and select *GOES 8*, then click the *Label* button and choose *Sat. Name*. Select *PLOT3D* in the *Display In* list. The GOES 8 orbit (in the geocentric reference frame) will appear in the Plot3D Window with the name shown next to the satellite marker (solid red circle). Since geosynchronous satellites hover above one Earth longitude, the geocentric orbit trace is a single point.

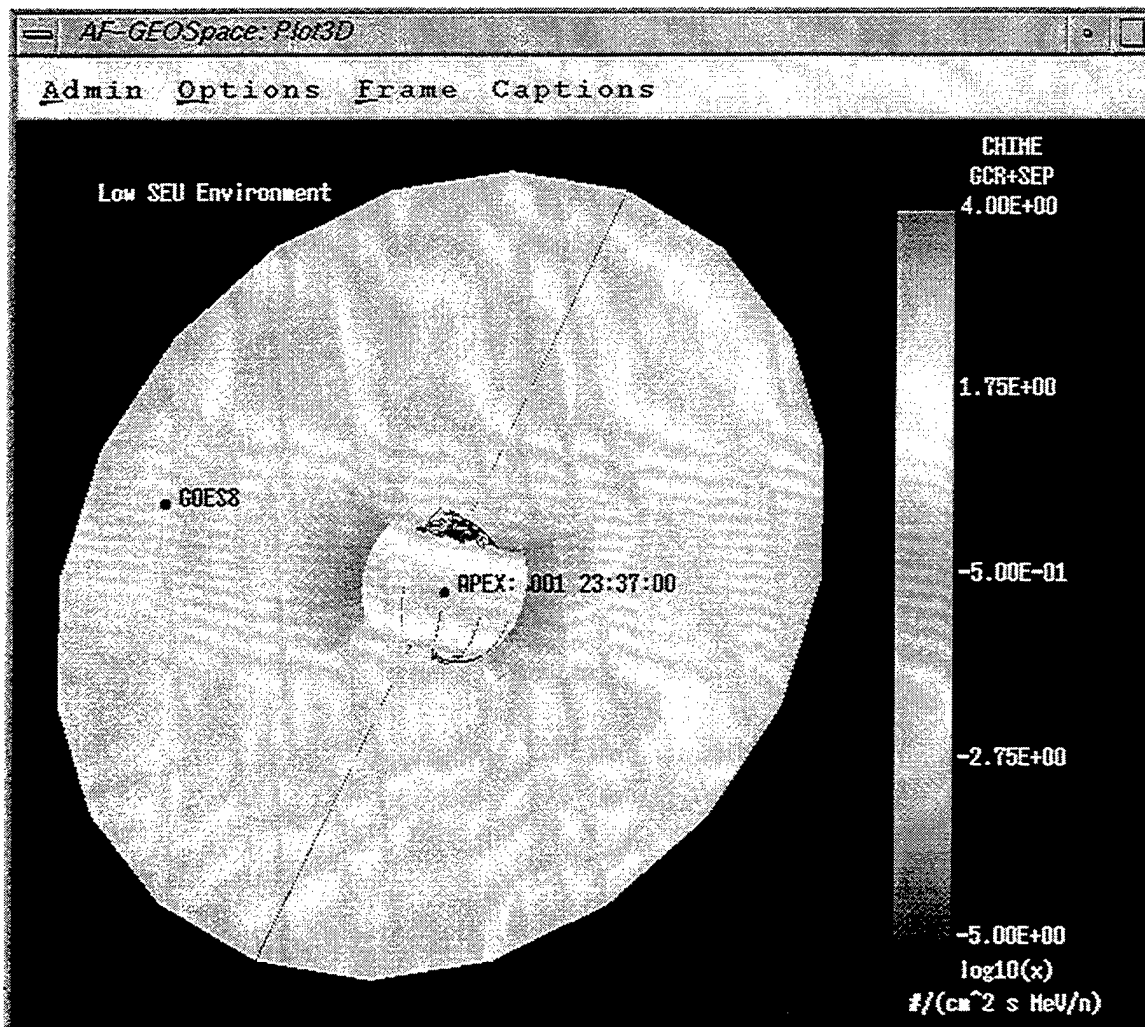
Display CHIME contours

- Scroll up the *Available Graphics Modules* list and select *COORD-SLICE*. A *COORD-SLICE* Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button, go to the *CHIME* option and select *GCR+SEP*. Click anywhere on the window background to register your choice. Under “Coordinate” select the *C2* option to get a constant longitude coordinate slice.
- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A two-dimensional coordinate slice of the CHIME model flux at a constant longitude will appear in the Plot3D Window. Move the *Position Value* slider to 0.25 (-90° E long).
- To change the color bar scale from linear to log, click on the *Transform* button on the right of the Environment Window. Edit the “y(x)” text window to read “log10(x)” and click the *Auto Range* button.
- Return to the *Available Graphics Modules* list and click twice on *COORD-SLICE*. A second *COORD-SLICE* Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button, go to the *CHIME* option and select *GCR+SEP*. Click anywhere on the window background to register your choice. Under “Coordinate” select the *C2* option to get a constant longitude coordinate slice.
- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A two-dimensional coordinate slice of the CHIME model flux at a constant longitude will appear in the Plot3D Window. Move the *Position Value* slider to 0.75 (+90° E long).
- To change the color bar scale from linear to log, click the *Transform* button on the right of the Environment Window. Edit the “y(x)” text to read “log10(x)” and click the *Auto Range* button.

Display CRRESPRO contours

- Return to *Available Graphics Modules* and click twice on *COORD-SLICE*. A third *COORD-SLICE* Object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click the *Data* button and select the *Flux* under the *CRRESPRO* option. Click anywhere on the window background to register your choice. Use the default “Coordinate” setting *C0* to display a constant radius slice.
- Select the *PLOT3D* line in the *Display In* list at the bottom of the window. A constant radius surface of the inner proton belt from the CRRESPRO model appears in the Plot3D Window.
- Adjust the *Position Value* slider to 0.20 (radius~1.40) so that the orbit is skimming the constant radial slice through the SAA flux peak.
- Change the color bar scale from linear to log clicking on the *Transform* button on the right of the Environment Window. Edit the “y(x)” text window to read “log10(x)” and click the *Auto Range* button.
- To change the color of the satellite label and orbit trace from red to black, select one of the *SATELLITE* objects in the *Active Graphics Modules* list. Click on the *Orbit Color* button and, in the new window that appears, move the *Red*, *Green*, and *Blue* sliders all the way to the left. Click *Apply* and then the *OK* button. Do the same for the second satellite.
- To change the satellite marker color from red to black, select one of the *SATELLITE* objects in the *Active Graphics Modules* list. Click on the *Marker* button, then click on the *Color* button that appears in the lower window. In the new window that appears, move all color sliders to the left, click on the *Apply* and then the *OK* button. Do the same for the second satellite.
- Since we are interested in comparing the low/high CHIME environments with the quiet/active CRESSPRO environments, we want to adjust the color scales on all Plot3D quantities to be the same (we already transformed all to log10 scale). To do this, return to the *Active Graphics Modules* list and select one of the three *COORD-SLICE* objects. Click on the *Transform* button and reset “Y Min” = -5 and “Y Max” = 4 and click on the *Update* button. Repeat this procedure for the two other *COORD-SLICE* objects in the *Active Graphics Modules* list.

The Plot3D Window should now resemble the following figure for the low SEU environment case (see end of example for high SEU environment related figures). Notice that for the low SEU environment, APEX encounters much higher SEU fluxes as it passes through the equator (from the proton belt) than it sees passing over the poles (from GCR). Due to its orbit, GOES 8 encounters much more modest fluxes (only from GCR). Note that although the color bar is labeled “CHIME GCR+SEP” the scale and units are the same as those used for the proton belt.



7) Create 1D Flux vs. time plot,

- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 1D Plot*. A Plot1D Window will appear.

APEX/CHIME,

- Scroll down the *Available Graphics Modules* list and click on *ORBIT-PROBE*. An ORBIT-PROBE object will be added to the *Active Graphics Modules* list and a set of Orbit Probe Options will appear in the Environment Window.
- Click the *Path/Abscissa* button, go to the *APEX* option and select *Time*. Click anywhere on the window background to register your choice.
- Click the *Data/Ordinate* button, go to the *CHIME* option and select *GCR+SEP*. Click anywhere on the window background to register your choice.

- Click on *PLOT1D* in the *Display In* list and CHIME output along the APEX orbit appears in the Plot1D Window. To move the satellite marker to match its position in the 3D window, adjust the *Position (%)* slider to .707.
- To change the y-axis from a linear to a log scale, click on the *Transform* button on the right of the Environment Window. Edit the “y’(y)” text window to read “log10(x)” and click the corresponding *Auto Range* button. Change the text boxes “Y Min” to -5.0 and “Y Max” to 4.0. Click the *Options* button, change “YTics” to 10, and click on the *Update* button.

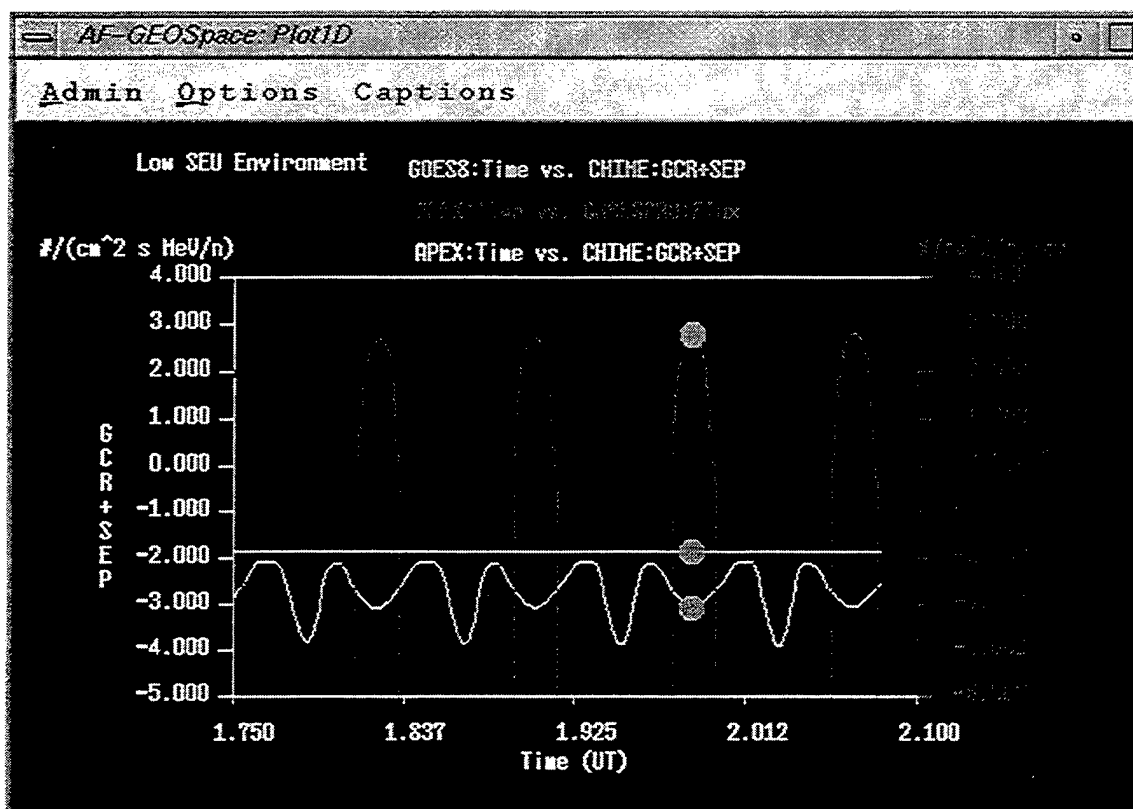
APEX/CRRESPRO,

- Return to the *Available Graphics Modules* list and click twice on *ORBIT-PROBE*. A second ORBIT-PROBE object will be added to the *Active Graphics Modules* list and a set of Orbit Probe Options will appear in the Environment Window.
- Click the *Path/Abscissa* button, go to the *APEX* option and select *Time*. Click anywhere on the window background to register your choice.
- Click the *Data/Ordinate* button, go to the *CRRESPRO* option and select *Flux*. Click anywhere on the window background to register your choice.
- Click on *PLOT1D* in the *Display In* list and CRRESPRO output along the APEX orbit appears in the Plot1D Window. To move the satellite marker to match its position in the 3D window, adjust the *Position (%)* slider to .707.
- To change the y-axis from a linear to a log scale, click on the *Transform* button on the right of the Environment Window. Edit the “y’(y)” text window to read “log10(x)” and click the corresponding *Auto Range* button. Change the text boxes “Y Min” to -5.0 and “Y Max” to 4.0 and click on the *Update* button.
- To further customize the 1D plot, select the *Options* button (on the right side of the Orbit Probe Options set) and set “Y-Axis” to be to the *Right* of the plot. Set “X-Axis” to *Off* (since CHIME and CRRESPRO share the time axis), change “YTics” to 10, and click on the *Update* button.

GOES 8/CHIME,

- Return to *Available Graphics Modules* and click twice on *ORBIT-PROBE*. A third ORBIT-PROBE Object will be added to the *Active Graphics Modules* list and a set of Orbit Probe Options will appear in the Environment Window.
- Click the *Path/Abscissa* button, go to the *GOES 8* option and select *Time*. Click anywhere on the window background to register your choice.
- Since the GOES 8 orbit does not pass through the inner belt, the CRRESPRO model is irrelevant - GOES 8 encounters no inner proton flux, and only CHIME contributes flux. Click the *Data/Ordinate* button, go to the *CHIME* option and select *GCR+SEP*. Click anywhere on the window to close the box.

- Click on *PLOT1D* in the *Display In* list and CHIME output along the GOES8 orbit appears in the Plot1D Window. To move the satellite marker to match its position in the 3D window, adjust the *Position (%)* slider to .707.
- To change the y-axis from a linear to a log scale, click on the *Transform* button on the right of the Environment Window. Edit the “y’(y)” text window to read “log10(x)”, and then click on the corresponding *Auto Range* button. Change the text boxes “Y Min” to -5.0 and “Y Max” to 4.0 and click on the *Update* button.
- Select the *Options* button and choose the *Off* position for the “X-Axis” and “Y-Axis” options. Change “YTics” to 10 and click on the *Update* button.
- To include a caption in this 1D plot, pull down the *Captions* menu on top of the Plot1D Window and select the *Show Captions* box. Pull down the *Captions* menu again and select *Caption Text*. In the pop-up window enter the text “Low SEU Environment” into the “Caption 1” text box (use the default x and y caption position coordinates). Click *Update* and close the window. Increase the Plot1D Window width and it should now resemble the following figure (see end of example for high SEU environment related figures).



In the above 1D figure, all contributions to our “Low SEU Environment” case are displayed using the same units (log10(flux) vs. time). As the APEX satellite progresses around its orbit it sees a large flux peak (blue line) once each orbit as it cuts through radiation belt protons that penetrate to lower altitudes near the SAA. The penetrating GCR particles, in contrast, are seen by APEX to

have a relative minimum near the equator as these particles are more efficient at penetrating closer to Earth near the magnetic poles. At geosynchronous altitude, GOES 8 sees only a steady lower magnitude contribution from GCR. It is clear for this low SEU case that the radiation belt protons are the largest source of SEUs for the lower altitude APEX satellite by five orders of magnitude.

8) Run the LET-APP Application Module for LEO satellite (APEX),

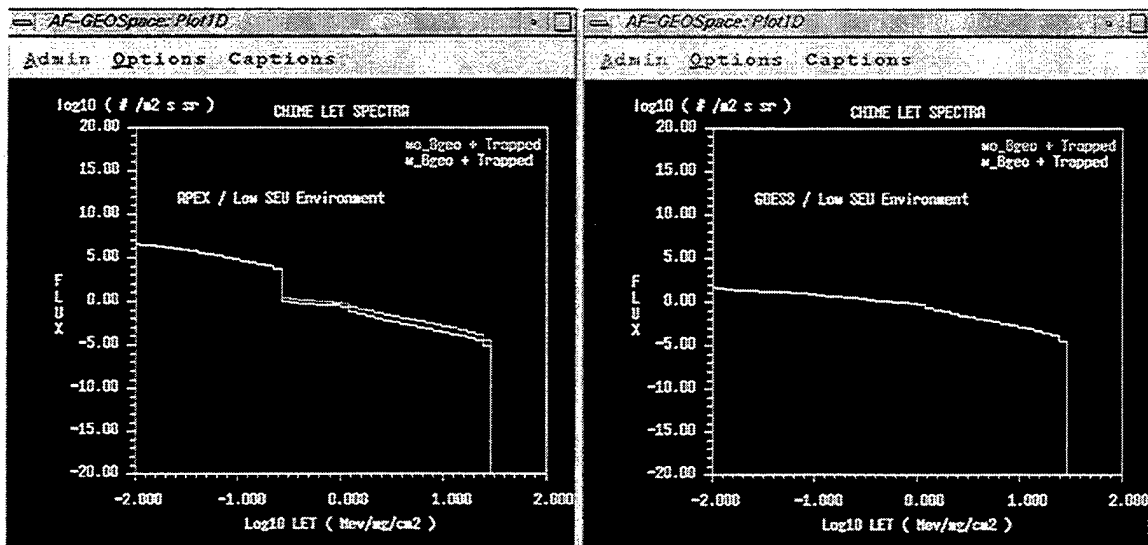
- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Click on *LET-APP* in the *Available Application Modules* list. A LET-APP object will be added to the *Active Application Modules* list and a set of Linear Energy Transfer (LET) Options will appear in the Environment Window.
- Under “Specify Environment”:
 - Click on the *Flux Inputs* button and select the *Period* option. This allows you to enter a specific time period for which the LET-APP program will determine an appropriate heavy ion flux level. Enter the beginning and end year/day into the appropriate text fields. For the low SEU environment (~solar maximum), enter “Year 1”=2004, Day 1”=1, “Year 2”=2004, “Day 2”=2. For the high SEU environment (~solar minimum), enter “Year 1”=1998, “Day 1”=1, “Year 2”=1998, “Day 2”=2.
 - Under the *Solar Events* button, use the default *off* setting for the low SEU environment. For the high SEU environment, select the *June 91 Peak* option to characterize the solar event environment using the peak fluxes from the June 1991 solar event.
 - Click on the *Atomic Z* button and select the *1 to 30* range option. This cuts down on computation time and will yield an adequate result for this illustrative example.
 - Click on the *Trapped Protons:* button for selection of inner proton belt model. For the low SEU environment select the *CRRESPRO Quiet* option. For the high SEU environment select the *CRRESPRO Active* option.
- Under “Specify Satellite / Device”:
 - For “Sat. Location:,” select the *From File* option and a Location File Window will appear. Click on the *Select File* button and a pop-up window will appear with a *Build list from file* list. Enter “\$AFGS_HOME/PLGS/examples/elements/*” in the “Filter” text window and click on the *Filter* button. Click on *APEX_94221.ELE* (or *goes94.txt* for the GOES 8 run, see Section 9) and then on the *OK* button. Select *APEX* (or *GOES 8* for GOES 8 run) from the *Current Element File* list. Edit the “T_start” text box to read “08/09/94 21:00:00” and the “T_stop” text box to read “08/09/94 23:00:00”. Click on the *Update* button in the lower corner. Close the window.
 - For “SEU device:,” use the default *Parameters* option.
 - The *Thickness* button allows you to specify the units of output results. Use defaults.
 - The *LET Set* button allows you to specify LET spectrum parameters. Use defaults.
- Click on the *Run Model* button at the bottom of the window. A Wait Window will appear with the message “Running LET calc....”

- When the model is complete the Wait Window will not disappear, but the status of the model will appear in the *Model Status* box in the lower part of the window. A CHIME Output Window will pop up (click to activate and remove the Wait Window) in which one of three sets of textual output is presented (depending on which is pre-selected). Options are described below.

View the results of the application,

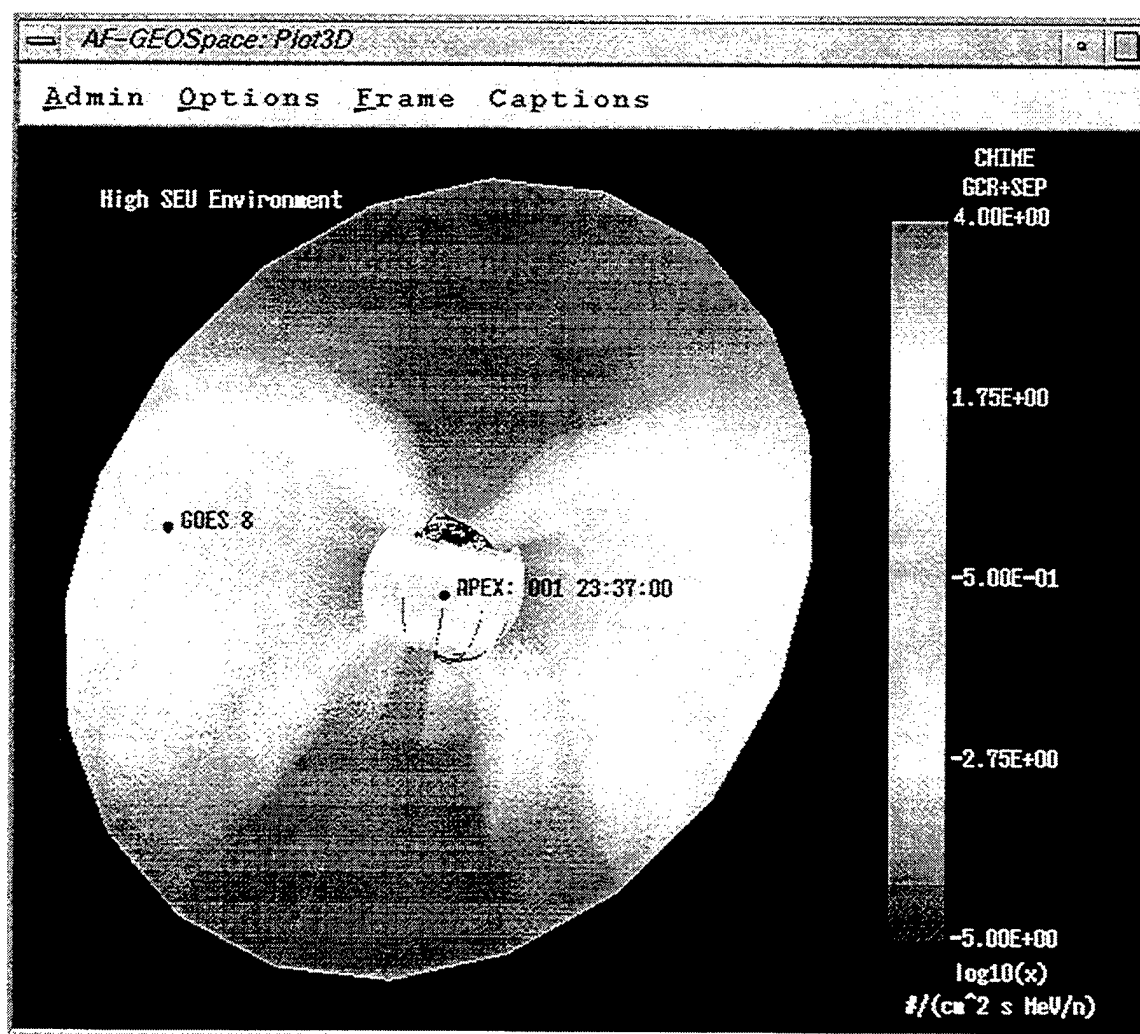
- Under “Control outputs”:
 - The *Text*: options (*SEU*, *LET*, and *LET/TRAPPED*) allow you to view various textual outputs. Click on *SEU* to view output from the SEU rate calculator; click on *LET* for LET Spectrum Output File; and *LET/TRAPPED* for Components of Integral LET spectra. There is an option to print the current text window under the *Admin* menu at the top of the CHIME Output Window.
 - Click on the *Display Plot* button to pop up a plot of an average LET spectrum. To further label this plot, pull down the *Caption Menu* on this plot window and select *Show Captions*. Pull down the *Caption Menu* again and select *Caption Text*. Enter “APEX / Low SEU Environment” in the “Caption 1” text box. Set the caption position to $x=.3$, $y=.75$. Click on the *Update* button and then close the window.

The Plot Window will display LET spectra for APEX matching the left side of the figure below. (The right side of the figure applies for the GOES8 example, see Section 9. See end of example for high SEU environment related figures).



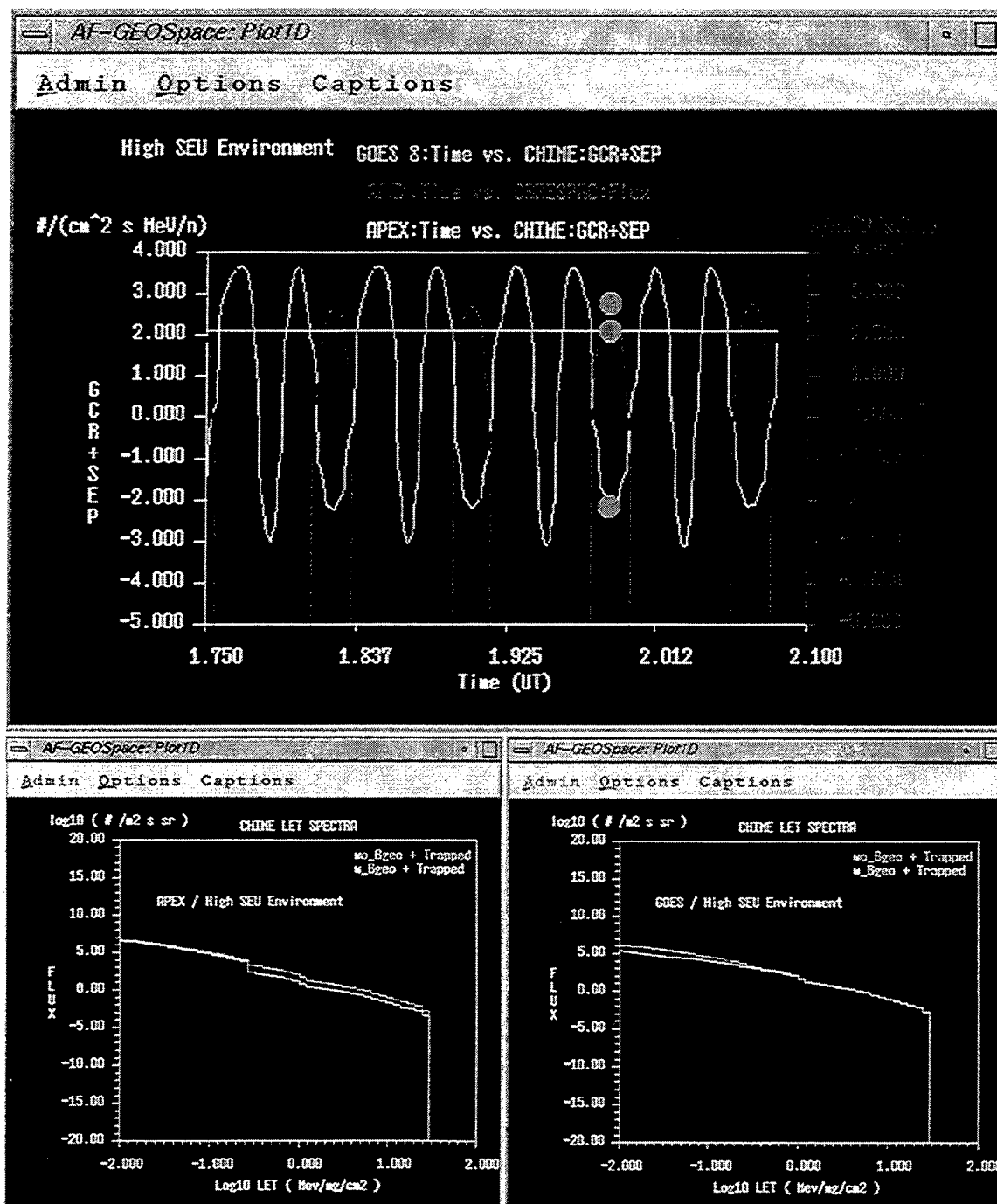
The LET spectrum plots in the above figure (APEX on the left, GOES8 on the right) represent the total flux of particles selected by the user with an energy deposit per “thickness” (MeV/mg/cm²). The two data lines represent the “worst” (blue line, without magnetic shielding) and “best” (white line, with magnetic shielding) case LET results. Note that slightly fewer particles reach the APEX orbit when magnetic shielding is considered. The “step” in the APEX plot results from the proton belt population near the equator. GOES8 is well above proton belt altitudes so its spectra are due solely to the GCR particles.

- 9) Run the LET-APP Application Module for GEO satellite (GOES8),
 - Repeat procedure #8, replacing *APEX* with *GOES8* and the LET spectra should resemble the right side of the figure above.
- 10) To compare the high and low SEU environments, repeat steps 1-9 for the high SEU environment (if you have the stamina). The resulting plots should resemble the figures below.



For the High SEU Environment shown in the figure above, the proton belt flux intensities at the APEX altitude have increased only slightly compared to the Low SEU Environment figure produced earlier. The solar energetic particles (SEP) included in this high SEU case, however, have dramatically increased the fluxes in the polar regions where APEX will now see them as the dominant source. While the geomagnetic field shields the equatorial region more effectively than the poles, the GOES8 satellite still sees significant increases with the addition of the SEP particles. Note that the sharp (red/green) gradient approximates the shape of the dipolar geomagnetic field line region shielding the lower latitude equatorial region from the higher particle fluxes.

The next plot shows the flux (log10) seen by APEX and GOES8 for a typical eight hour period for the same High SEU Environment. Once again, compared with the low SEU case, the proton belt flux peak seen by APEX once an orbit (blue line) near the equatorial SAA has increased only slightly. Major flux increases from the SEP particles included in this high SEU case are seen by GOES8 at geosynchronous altitude and by APEX as it crosses the poles.



The two LET spectra plots at the bottom of the above figure for the High SEU Environment case (APEX left, GOES8 right) illustrate the dramatic impact of including the SEP population in the CHIME calculation. For APEX, the SEP contribution has filled in the “step” present in the low SEU case shown earlier and shows overall flux increases for the higher LET values. For GOES8 the spectral flux is elevated overall by several orders of magnitude.

This completes the Example of the Single Event Upset Environment.

5) The Earth's Magnetic Field: Placement of the Current Sheet

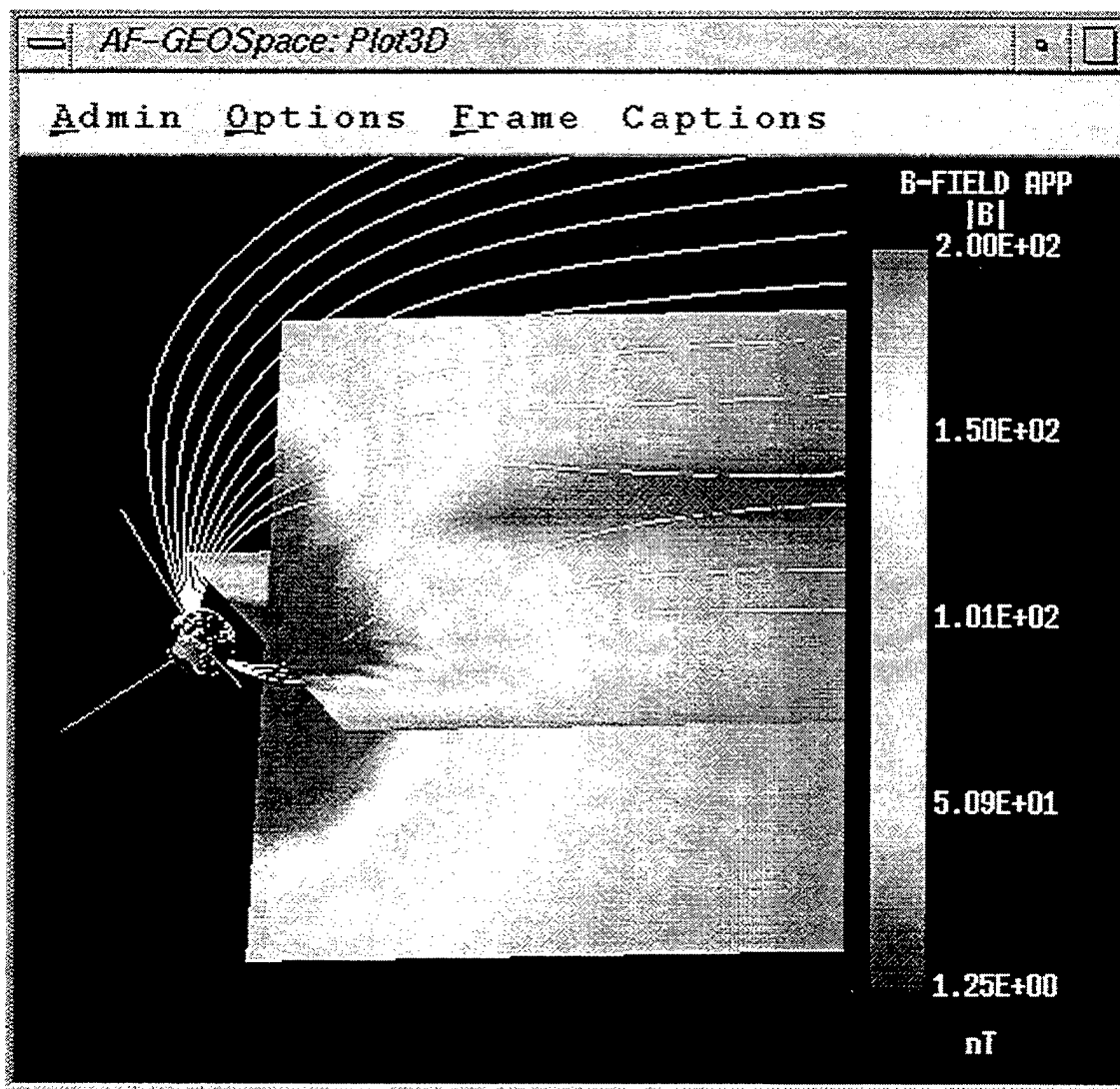
The following example demonstrates the use of the magnetic field BFIELD-APP Module, the FIELD LINES Graphics Module, and a variety of other visualization tools.

Goal: The solar wind interacts with the Earth's intrinsic magnetic field to form a magnetic cavity called the magnetosphere. Solar wind pressure (from particles and magnetic field) compresses the magnetosphere on the dayside and helps to form an extended magnetotail of several hundred Earth radii in length on the nightside. The overall interaction results in a sheet of westward traveling current on the nightside that separates a region of anti-sunward directed field lines from a region of sunward directed field lines, i.e., magnetic field lines emanate from the south pole and extend down the magnetotail before passing up through the cross-tail current sheet and returning to Earth to connect at the north pole. In addition, the placement of the cross-tail current sheet (where the magnetic field lines change polarity) changes as a function of Earth's dipole tilt angle relative to the solar direction. The goal of this example is to examine the placement of the current sheet and the magnetic field lines near the midnight meridian at a time when the dipole tilt angle is large.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Adjust the global parameters to represent a moderate magnetic activity level at a time when there is a large dipole tilt angle, e.g., set "Year"=1989, "Day"=160, "UT"=15:00. Click on the *Globals Archive* button to automatically load input parameter values from the archived NGDC data ("Kp"=3.3, "SSN"=168, "F10.7"=241.9, and "Ap"=18). Note that the only global parameters affecting the magnetic field configurations are the Day, UT, and Kp.
- Choose *Modules* from the Menu Bar and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Select *BFIELD-APP* from the *Available Application Modules* list. A BFIELD-APP object will appear in the *Active Application Modules* list and options for B-Field Application Parameters will appear in the Environment Window.
- Under "Generate" select the *Gridded Data* and *MLT Field Lines* options. Select the "Internal B-Field" option *Centered Dipole* and the "External B-Field" option *Tsyganenko '89*. From the Tsyganenko '89 Window that appears pick the *Kp Only* option and close the window.
- To view field lines in or near a meridian they must originate from a constant Magnetic Local Time (MLT). Set the "MLT Field Line Inputs" to "MLT"=0, "MLAT0"=65, "MLAT1"=85, and "Steps"=10. With these settings, field lines from local midnight will be separated by 2 degree increments between 65 and 85 degrees latitude.

- Because the magnetotail aligns itself along the Earth-Sun direction (which defines the XGSM axis), the Geocentric Solar Magnetospheric (GSM) cartesian system is the most appropriate for this example. To set up a 3D grid in this coordinate system, click on the *Grid Tool* button at the bottom of the Environment Window. At the top of the Grid Setup Window that appears, use the pulldown menus to select “Spacing” = *Linear*, “Geometry” = *Cartesian* and “System” = *GSM* and the coordinates listed below will change to X, Y, and Z, GSM (Re). To form a 20 by 20 by 20 Earth radii grid in the magnetotail set all values of “NPoints”=20, set the X range with “Min”=-22, “Max”=-2, and the Y and Z ranges with their “Min”=-10 and “Max”=10. Click the *Apply* button to setup the grid and close the Grid Setup Window. A red Wait Window will appear briefly.
- Click on the *Run Model* button at the bottom of the Environment Window to start the calculation of the MLT field line traces and complete the gridded data set. A Wait Window appears briefly. When complete, the *Model Status* box lists the dipole tilt angle for the selected time (32.6 degrees), the Kp range in use, and notes that the model is ready and up to date.
- From the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window for displaying 3D gridded data sets will appear.
- Return to the Menu Bar, click on the *Modules* menu and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of Earth Options will appear in the bottom of the Environment Window.
- Under “Outline Detail” select the *Filled* (to color the continents) and *Geographic Bndys* options. Click on *PLOT3D* in the *Display In* box to place the Earth in the Plot3D Window. The left and center mouse buttons can be used to rotate and scale the Earth image while the cursor is in the Plot3D Window.
- Select *AXES* from the *Available Graphics Modules* list and an AXES object will be added to the *Active Graphics Modules* list. Change the “Axes Frame” from the default setting (GEOC) to *SM*. We selected the Solar Magnetic (SM) coordinate axis because the Earth’s magnetic dipole is aligned with the SM Z-axis (see the Grid Tool section of the documentation for coordinate system definitions). Click on *PLOT3D* in the *Display In* list and a set of orthogonal axes in the SM coordinate system will appear. Notice that the North magnetic pole (blue axis) is located near Greenland.
- To display magnetic field lines, return to the *Available Graphics Modules* list and select *FIELD-LINES*. A FIELD-LINES object appears in the *Active Graphics Modules* list and a set of Field-Lines Options appears in the Environment Window.
- Click on the *Data* button, go down to *B-FIELD APP* and choose *Field Lines-MLT*. Click on the window background to register your choice. Choose *Field Lines* as the “Plot Type”. Click on the *Choose Color* button, pull down the *Options* menu, choose *White*, and click *OK*. Click on *PLOT3D* in the *Display In* list to display the white field lines in the Plot3D Window.

- Use the first two mouse buttons while the cursor is in the Plot3D Window to rotate and rescale the image. By increasing the viewing distance we see that some of the field lines close in the southern hemisphere while the higher latitude magnetic lines are open and extend well beyond our view. Rotating the Earth to view either pole region we see that the midnight field lines are coplanar.
- To display the magnetic field magnitude values stored on our GSM grid, select *COORD-SLICE* from the *Available Graphics Modules* list. A COORD-SLICE object appears in the *Active Graphics Modules* list and a set of Coordslice Options appears in the Environment Window.
- Click on the *Data* button and under the *B-FIELD APP* option choose *|B|*. Click on the window background to register your choice of data. With our grid setup the coordinates *C0*, *C1*, and *C2* correspond to GSM X, Y, and Z, respectively. To get a contour of magnetic field strength in the Z-GSM plane select “Coordinate” *C2* and click on *PLOT3D* in the *Display In* list. Position this coordinate slice in the field line reversal region by moving the *Position Value* slider to a value of 0.725. This location corresponds to $Z_{GSM} = 4.5 R_E$ and indicates that the finite tilt angle (32.6 degrees) has lifted the current sheet significantly above the GSM $Z=0$ plane. Return the slider to the value 0.500, where $Z = 0 R_E$.
- Magnetic field strength decreases with geocentric distance roughly as R^{-3} so we will adjust the contour color scale to better highlight field magnitude variations in the middle magnetosphere. Click the *Transform* button in the Environment Window and reset the value of “Max” to 200 (nT) in the Data Transformation Parameters panel that appears. Click the *Update* button.
- To display another coordinate slice of magnetic field magnitude values, return to the *Available Graphics Modules* list and click twice on *COORD-SLICE*. A second COORD-SLICE object will be added to the Active Graphics Modules list and a new Coordslice Options set appears in the Environment Window.
- Click on the *Data* button, and under the *B-FIELD APP* option, choose *|B|*. Click on the window background to register your choice. To get a contour of magnetic field strength in the Y-GSM plane select “Coordinate” *C1* and click on *PLOT3D* in the *Display In* list. Adjust the contour color scale as done in the previous step so that the $y = 0$ slice scale matches that of the $z = 0$ slice, i.e., click the *Transform* button, reset “Max” to 200, and click the *Update* button.
- Notice that the minimum field strength region (dark blue) corresponds to the magnetic field reversal region. This minimum field strength region is also the location of the cross-tail current system that contributes to the sharp field reversal. The Plot3D Window should now resemble the figure on the next page in which the Sun is directly off to the left.
- To reproduce this figure more closely, go to the *Admin* menu at the top of the Plot3D Window and select the *Show View* option. In the Viewer Window that appears, move the sliders so that they are set at approximately *Latitude* = 25, *Longitude* = 39, *Twist* = 340, *Scale* = 0.65, *Zoom* = 1.0, *Translate X* = 2.0, *Translate Y* = -4.1, and *Translate Z* = 0.8. Close the Viewer Window. Mouse buttons can also be used to achieve this view (for instructions select *Show Hints* from the *Options* menu in the Plot3D Window).



This completes the Example of The Earth's Magnetic Field: Placement of the Current Sheets.

6) UHF/L-Band Scintillation on a Geostationary Satellite Downlink

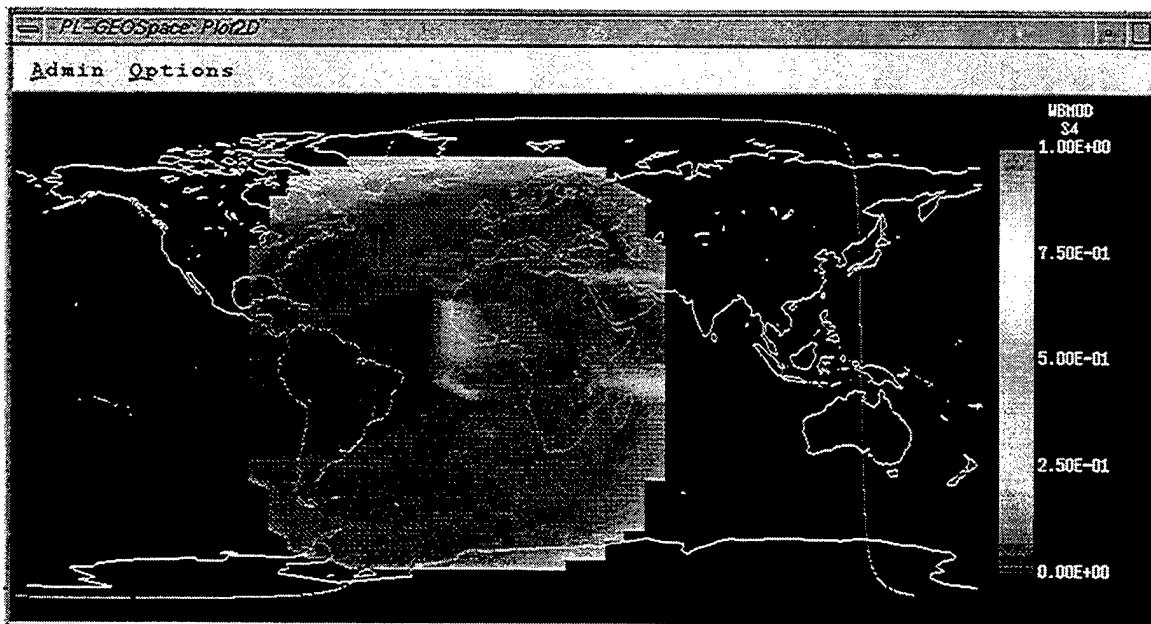
The following example demonstrates the use of the WBMOD (WideBand Model) Science Module and a variety of other visualization tools.

Goal: The WideBand Model (WBMOD) specifies scintillation parameters between locations on the globe and a satellite above 100 km altitude as a function of signal frequency and geomagnetic activity. Scintillation is the rapid amplitude and phase fluctuations of signals passing through ionospheric irregularities. The goal of this example is to determine where the disturbance level of scintillation (S4) of UHF (250 MHz) and L-Band (1500 MHz) signals will be severe at least 10% of the time for ground-based receivers within the footprint of a geostationary satellite under moderately active solar/magnetic conditions.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Set the Global Parameters as follows: "Year"=1990, "Day"=260, "UT"=21:00. The "Kp" and "SSN" (sunspot number) corresponding to the specified date and time may now be obtained by clicking on the *Globals* button *Archive* option. The NGDC archived values of these parameters are then automatically loaded ("Kp"=3, "SSN"=137, "F10.7"=210.7, and "Ap"=15). Note that "Year", "F10.7" and "Ap" are not used by WBMOD. These parameters describe conditions following passage of the solar terminator in the Euro-African longitude sector during moderate magnetic and solar activity conducive to the development of scintillation near the magnetic equator on September 17, 1990.
- Choose *Modules* from the Environment Window Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Scroll to the bottom of the *Available Science Modules* list and click on *WBMOD*. A WBMOD object will be added to the *Active Science Modules* list and a WBMOD Options panel will appear in the Environment Window. To model the upper 10% (90th percentile) of 250 MHz scintillation observed on the ground from a geostationary satellite located over the Atlantic Ocean set the WBMOD options: "Propagation"=1-way, "In-situ Vd"=Model, "Step"=Rcvr, "EP Boundary"=Use Kp, "Output"=Percentile, "Trans. Freq (MHz)"=250, "Trans. Alt. (km)"=36000, "Fixed End Lat"=0, "Fixed End Lon"=-15, "Phase Stability(s)"=10, "Percentile"=0.9, and "Kp@LocalSunset"=-1. All other parameter settings remain inactive.
- Click on the *Run Model* button in the bottom left of the Environment Window. The *Model Status* box will indicate the Global Parameters being used to construct the model run. When the run is complete the Wait Window will disappear and the *Model Status* box will be updated with the text "MODEL IS READY AND UP TO DATE."

Plot UHF WBMOD Results in 2D,

- At the top of the Environment Window, click on *Windows* and select *Create 2D Plot*. A Plot2D Window will appear containing only an unlabeled colorbar.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and an EARTH Options panel will appear in the bottom of the Environment Window.
- Select *Terminator* under “Grid Options”.
- Select *PLOT2D* in the *Display In* box in the Environment Window and click on the *Update* button. After several seconds a two-dimensional map of the Earth will be displayed in the Plot2D Window; a purple line shows the location of the solar terminator at the surface.
- Select *COORD-SLICE* from the *Available Graphics Modules* list. A COORD-SLICE object will be added to the *Active Graphics Modules* list and a corresponding options panel will appear in the bottom of the Environment Window.
- Under “Coordslice Options” click on the *Data* button, slide down the popup menu to the *WBMOD* option, and select *S4*. Click anywhere on the window to register your choice.

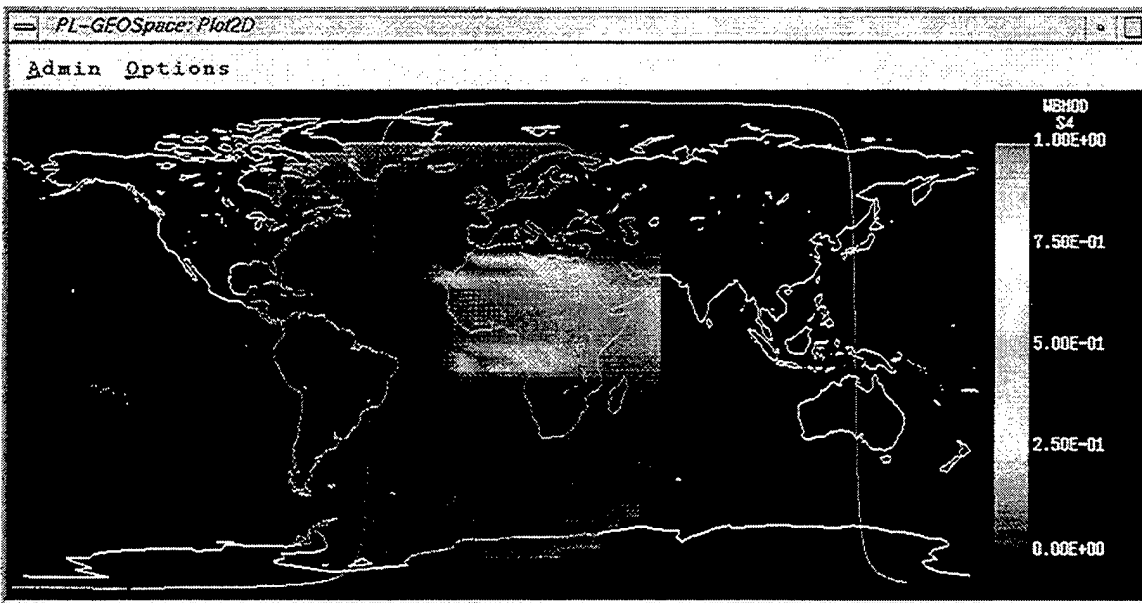


- Select *PLOT2D* in the *Display In* box at the bottom of the Environment Window to display the scintillation results on the 2-D map. Click on the *Update* button in the Coordslice Options panel to display the scale markers on the colorbar in the plot. The Plot2D Window should resemble the figure above.

- The exact display above is achieved by selecting the *Transp.* button in the Coordslice Options panel to add transparency to the solid colormap. Increase transparency of the solid colormap by moving the *Alpha Value* slide bar with the mouse so that the *Alpha Value* = 0.7. This provides good data image brightness while making underlying geographic features visible.

Create WBMOD Model Output for L-band (1.5 GHz),

- Return to the Menu Bar at the top of the Environment Window, click on *Modules* then *Science* and click twice on *WBMOD* in the *Available Science Modules* list, and a second *WBMOD* entry appears in the *Active Science Modules* list on the right. The *WBMOD* Options panel will appear in the bottom of the Environment Window.
- To model the upper 10% (90th percentile) of 1500 MHz scintillation observed on the ground from a geostationary satellite located at the equator over the Atlantic Ocean set the following *WBMOD* options: “Propagation”=1-way, “Step”=Rcvr, “Output”=Percentile, “Trans. Freq (MHz)”=1500, “Trans. Alt. (km)”=36000, “Fixed End Lon”=-15, and “Percentile”=0.9. All other *WBMOD* parameters may be left at the default values. These inputs are the same as those entered to get the existing 2D plot except for the increase in “Trans. Freq (MHz)”. Note that the Global Parameters at the top of the Environment Window set earlier do not change.
- Click on the *Run Model* button at the lower right of the Environment Window. After the Wait Window has disappeared and the *Model Status* box has been updated, there is a second *WBMOD* data set available for display.
- Return to the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 2D Plot*. A second *Plot2D* Window will appear with only the unlabeled colorbar.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear. The *Active Graphics Modules* list will already contain *EARTH* and *COORD-SLICE* objects from the UHF results plot. Select *EARTH* from the *Active Graphics Modules* list. Hold down the shift key and click on the second *PLOT2D* line in the *Display In* box so that both *PLOT2D* entries are highlighted. After several seconds the Earth map and terminator indicator will also be displayed in the new window.
- Select *COORD-SLICE* from the *Available Graphics Modules* list. A second *COORD-SLICE* object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the bottom of the Environment Window.
- Under “Coordslice Options” click on the *Data* button, slide down the popup menu to the *WBMOD* option, and select *S4*. Click any where on the window to register your choice.
- Select the lower *PLOT2D* line in the *Display In* box at the bottom of the Environment Window to display the scintillation results on the new two-dimensional map. Click on the *Update* button in the Coordslice Options panel to display the scale markers on the colorbar in the plot.
- To reproduce the following figure, click on the *Transp.* button and set the *Alpha Value* to 0.7.



Interpretation of Results: The results indicate that the 90th percentile of S4 index at 250 MHz within 20 degrees of the magnetic equator over most of Africa at 21:00 UT will be unity, i.e., severely scintillated at least 10% of the time (i.e., 1 out of 10 days) for the geophysical conditions specified (see first plot made). Recall, for the step-receiver mode, the data will be plotted at the receiver location, not at the ionospheric location where scintillation occurred. Similarly, in the step-transmitter mode, data is for scintillation on the ray-path from the satellite to the receiver and plotted at the sub-satellite point. This display location would not be the ionospheric location where the scintillation occurred. As expected, the level of scintillation experienced by L-band (1.5 GHz) signals is substantially lower over most of the affected region (see second plot). The 95th percentile fade (dB) can be displayed by returning to the Coordslice Options panel (select *Graphics* under the *Modules* menu, click on the second *COORD-SLICE* in the *Active Graphics Modules* list) and selecting *95%tile FADE* from the second of the *WBMOD Data* options. Click on the background of the Environment Window to complete the selection procedure and then click on the *Update* button to update the display and scale the colorbar. Both UHF and L-band results may be obtained in this manner by selecting the *COORD-SLICE* entry that corresponds to each frequency. Don't confuse this percentile with the climatological percentile input to run WBMOD. For example, we selected a 90th percentile climatology for this example. This display represents the 5th most severe fade on the 10th most disturbed day. Recall, that scintillation is the rapid fluctuation of the signal's amplitude and phase. Therefore, if any of the fades are below the receiver's fade-margin even for small amounts of time, this may be enough to cause communication problems, especially if the message is encrypted.

This completes the Example of UHF/L-Band Scintillation on a Geostationary Satellite Downlink.

7) The Magnetospheric Cusp and Auroral Equatorward Boundary

The following example demonstrates the use of the AURORA Science Module, the magnetic field BFIELD-APP Module, the FIELD-LINES Graphics Module, and a variety of other visualization tools.

Goal: Magnetospheric magnetic fields contribute to the particle precipitation patterns observed in the polar caps, i.e., the magnetic cusp is associated with a peak in ion precipitation near noon magnetic local time and plasma sheet electrons follow magnetic field lines down to the ionosphere to help form the auroral oval. To illustrate these magnetic field-particle precipitation connections, the goal of this example is two-fold: (1) Examine the location of the magnetospheric cusp and its mapping as determined by several magnetic field models in relation to statistically determined auroral ion number fluxes; (2) Examine the location of the equatorward boundary of the auroral region, as determined by the electron number flux, and visualize its magnetic connection to the equatorial region of the magnetosphere.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Edit the global parameter text boxes such that "Year"=1993, "Day"=81, and "UT"=9:00. This was a magnetically activity time having a modest dipole tilt angle. Click on the *Globals* button *Archive* option to automatically load input parameter values from the archived NGDC data ("Kp"=4.3, "SSN"=73, "F10.7"=126.6, and "Ap"=32). Note that SSN, F10.7, and Ap will not be used by the modules used in this example.

Create and plot an aurora ion data set,

- Choose *Modules* from the Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *AURORA* in the *Available Science Modules* list. An *AURORA* object will appear in the *Active Science Modules* list and a set of *AURORA Options* will appear in the Environment Window.
- Leave the "Generate", "Internal B-Field", and "External B-Field" selections as *Gridded Data*, *Centered Dipole*, and *None*, respectively. Click on the *Grid Tool* button at the bottom of the Environment Window and a *Grid Setup Window* will appear. Note that the radius minimum and maximum settings are the same because the default auroral grid is simply a surface at ionospheric altitude. To get a smoother contour plot, increase "NPoints" for the "Lat" coordinate to 100 and increase "Npoints" for the "Lon" coordinate to 96. Hit the *Apply* button to generate the grid and close the *Grid Setup Window* (a red Wait Window appears briefly).

- Click the *Run Model* button at the bottom of the Environment Window to load auroral model information onto the grid. The *Model Status* box will show the global parameters used and indicate that the model is ready after the red Wait Window vanishes.
- From the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window for displaying 3D gridded data sets will appear.
- Return to the Menu Bar, click on the *Modules* menu and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of Earth Options will appear in the bottom of the Environment Window.
- Under “Outline Detail” leave *Geographic Bndys* checked off and under “Grid Options” select *Lat/Lon Grid*. To get 10 degree latitude and longitude grid divisions, edit the text boxes to read “Lat Res”=19 and “Lon Res”=36. Click on *PLOT3D* in the *Display In* list to plot the gridded Earth in the Plot3D Window.
- While the cursor is in the Plot3D Window, the left and center mouse buttons can be used to rotate and resize the view of Earth, respectively. Use the center mouse button to rescale the view so that the Earth fills a large portion of the Plot3D Window. Now use the left mouse button to rotate the Earth downward so you can view the north pole.
- From the *Available Graphics Modules* list select *COORD SLICE* to view the ion number fluxes. A COORD-SLICE object will be added to the *Active Graphics Modules* list and a set of Coordslice Options will appear in the Environment Window.
- Click on the *Data* button and select *Ion Number Flux* under the AURORA options list that appears. Click on the background of the Environment Window to register your selection. Note that the default “Coordinate” *C0* corresponds to a fixed geocentric radial distance.
- Select *PLOT3D* in the *Display In* box to view the ion number flux. Click on the *Transform* button and set “Min” = 6.0 in the Data Transformation Parameters options that appear at the bottom of the Environment Window. Click on the *Windows* button to implement this change and return to the window display list.
- To make the ion number flux coordinate slice transparent click on the *Transp.* button, move the *Alpha Value* slider to 0.8, and click on the *Windows* button. Notice the flux maximum near 80 degrees geographic latitude just east of the Greenwich meridian.

Create and plot cusp magnetic flux tubes from different magnetic field models,

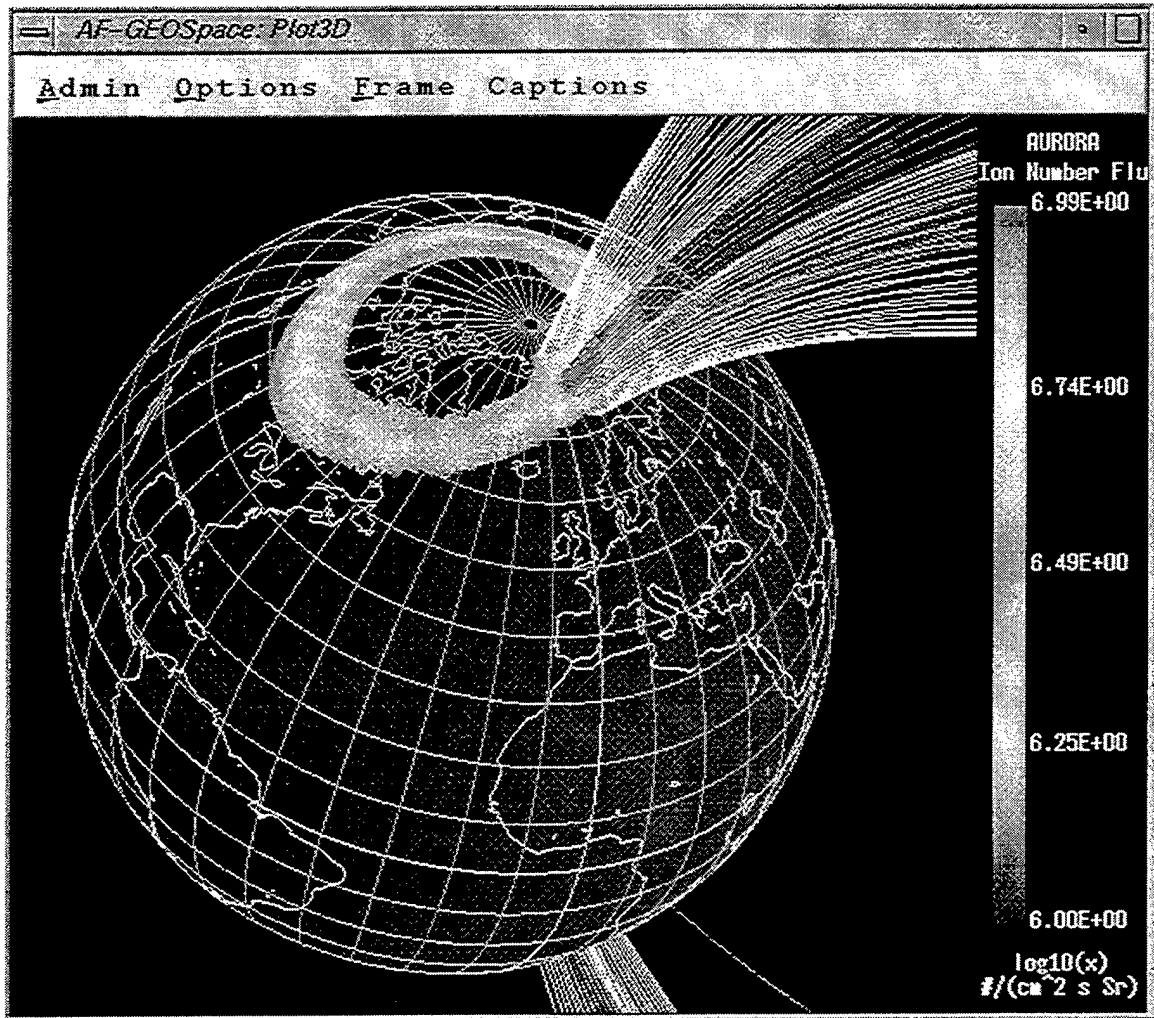
- To check the location of magnetic field model cusps relative to the ion number flux we will plot magnetic flux tubes centered approximately about their respective magnetic cusps. If centered properly, the flux tube field lines will continue to spread as they approach the magnetopause. Some field lines will pass through the magnetic equator and connect to the opposite hemisphere while others are swept anti-sunward into the magnetotail.

- B-field Case 1: Return to the *Modules* menu and select *Applications* from the options. *Available Application Modules* and *Active Application Modules* lists will appear.
- Select *BFIELD-APP* from the *Available Application Modules* list. A *BFIELD-APP* object will appear in the *Active Application Modules* list and options for B-field Application Parameters will appear in the lower portion of the Environment Window.
- Under “Generate” check the *Flux Tube* option (the *Gridded Data* and *MLT Field Lines* options will not be used and can be unchecked) and under “Internal B-Field” select the *IGRF(1945-2000)* option.
- Select the *Hilmer-Voigt ‘95* “External B-Field” model and choose the *Kp Only* option in the Hilmer-Voigt ‘95 Window that appears. Close the window using the menu that appears while clicking the tab on the left of the title bar.
- Set the Hilmer-Voigt “Flux Tube Inputs” coordinates to *Geographic* and set “Lat”=75, “Long”=21, “Alt(km)”=0, “Diam(km)”=600, and “Steps”=40. Hit the *Run Model* button. After the flux tube field line traces are complete the Wait Window will disappear and the *Model Status* box will show the internal model settings that correspond to the global Kp = 4.
- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *FIELD-LINES* from the *Available Graphics Modules* list. A *FIELD-LINES* object will appear in the *Active Graphics Modules* list and a set of Field-Lines Options will appear in the Environment Window.
- Click on the *Data* button, slide down to *B-FIELD APP*, and select the *Flux Tube* option. Click on the window background to register your choice. Click the *Choose Color* button and move the *Red* and *Green* sliders to the extreme right and the *Blue* slider to the left to make the “Current Color” yellow. Click the *OK* button and the Hilmer-Voigt flux tube field lines will be assigned the color yellow. Click on *PLOT3D* in the *Display In* list to plot the field lines.
- Use the center mouse button while the cursor is in the Plot3D Window to zoom out until field lines can be seen hitting the southern hemisphere. Some field lines connect to the southern hemisphere while others hit the magnetopause. Now zoom in very close until only the footprint of the flux tube is showing and notice that the magnetic cusp in this model is centered a few degrees equatorward of the statistical ion number flux maximum shown in red.
- B-field Case 2: Return to the *Modules* menu and select *Applications*. Click twice on *BFIELD-APP* in the *Available Application Modules* list and a second *BFIELD-APP* object will appear in the *Active Application Modules* list on the right (the existing active module is our Hilmer-Voigt flux tube to be saved for comparison). Once again select the *Flux Tube* and *IGRF(1945-2000)* options, but this time choose the “External B-Field” *Olson-Pfizer ‘77* option.
- Set the Olson-Pfizer “Flux Tube Inputs” coordinates to *Geographic* and set “Lat”=83, “Long”=13, “Alt(km)”=0, “Diam(km)”=600, and “Steps”=40. Hit the *Run Model* button. Note

in the *Model Status* box that this model does not use the global input Kp (in fact this model represents an average quiet state of the magnetosphere).

- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Click twice on *FIELD-LINES* from the *Available Graphics Modules* list. A second *FIELD-LINES* object will appear in the *Active Graphics Modules* list and a set of Field-Lines Options will appear in the Environment Window.
- Click on the *Data* button, slide down to the second *B-FIELD APP* listed and select the *Flux Tube* option. Click on the window background to register your choice. Select the *Choose Color* button, select *White* from the color window *Options* menu, and click *OK*. Click on *PLOT3D* in the *Display In* list to plot these new field lines. Zoom in to see that the Olson-Pfizer model magnetic cusp is several degrees poleward of the ion number flux maximum.
- B-field Case 3: Return to the *Modules* menu and select *Applications*. Click twice on *BFIELD-APP* in the *Available Application Modules* list and a third *BFIELD-APP* object will appear in the *Active Application Modules* list on the right. Once again select the *Flux Tube* and *IGRF(1945-2000)* options, but this time choose the *Tsyganenko '89* model for the “External B-Field” option. Pick the *Kp Only* option from the *Tsyganenko '89* Window that appears and close the window.
- Set the *Tsyganenko '89* “Flux Tube Inputs” coordinates to *Geographic* and set “*Lat*”=78, “*Long*”=18, “*Alt(km)*”=0, “*Diam(km)*”=600, and “*Steps*”=40. Click the *Run Model* button and the *Model Status* box shows the Kp model used and indicates the flux tube field lines have been traced.
- Choose *Modules* from the Menu Bar and select *Graphics* from the options. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Click twice on *FIELD-LINES* from the *Available Graphics Modules* list. A third *FIELD-LINES* object will appear in the *Active Graphics Modules* list and a set of Field-Lines Options will appear in the Environment Window.
- Click on the *Data* button, slide down to the third *B-FIELD APP* listed, and select the *Flux Tube* option. Click on the window background to register your choice. Click the *Choose Color* button and move the *Red* slider right and the *Green* and *Blue* sliders left to make the “Current Color” red. Click the *OK* button and the *Tsyganenko* flux tube field lines will be assigned the color red. Click on *PLOT3D* in the *Display In* list to plot the field lines. Notice that the *Tsyganenko '89* red cusp flux tube seems centered fairly well about the ion number flux maximum.
- Easier comparisons can be made by using the mouse button to rotate and scale the picture while selectively turning the field-line displays on and off. Hide a set of field lines by selecting one of the *FIELD-LINES* objects listed in the *Active Graphics Modules* list and click the *On/Off* button. Remember that the active graphic objects and the data sets are listed in the order produced: *Hilmer-Voigt '95* (Yellow), *Olson-Pfizer '77* (White), and *Tsyganenko '89* (Red).

- The figure below can be obtained by rotating and scaling the view with the left and center mouse buttons, respectively. By viewing one set of cusp field lines at a time and selecting the *Filled Surface* “Plot Type” option the true funnel formed by the cusp magnetic field lines becomes more evident. The color scale labels will display while the COORD-SLICE entry in the *Active Graphics Modules* list is highlighted.

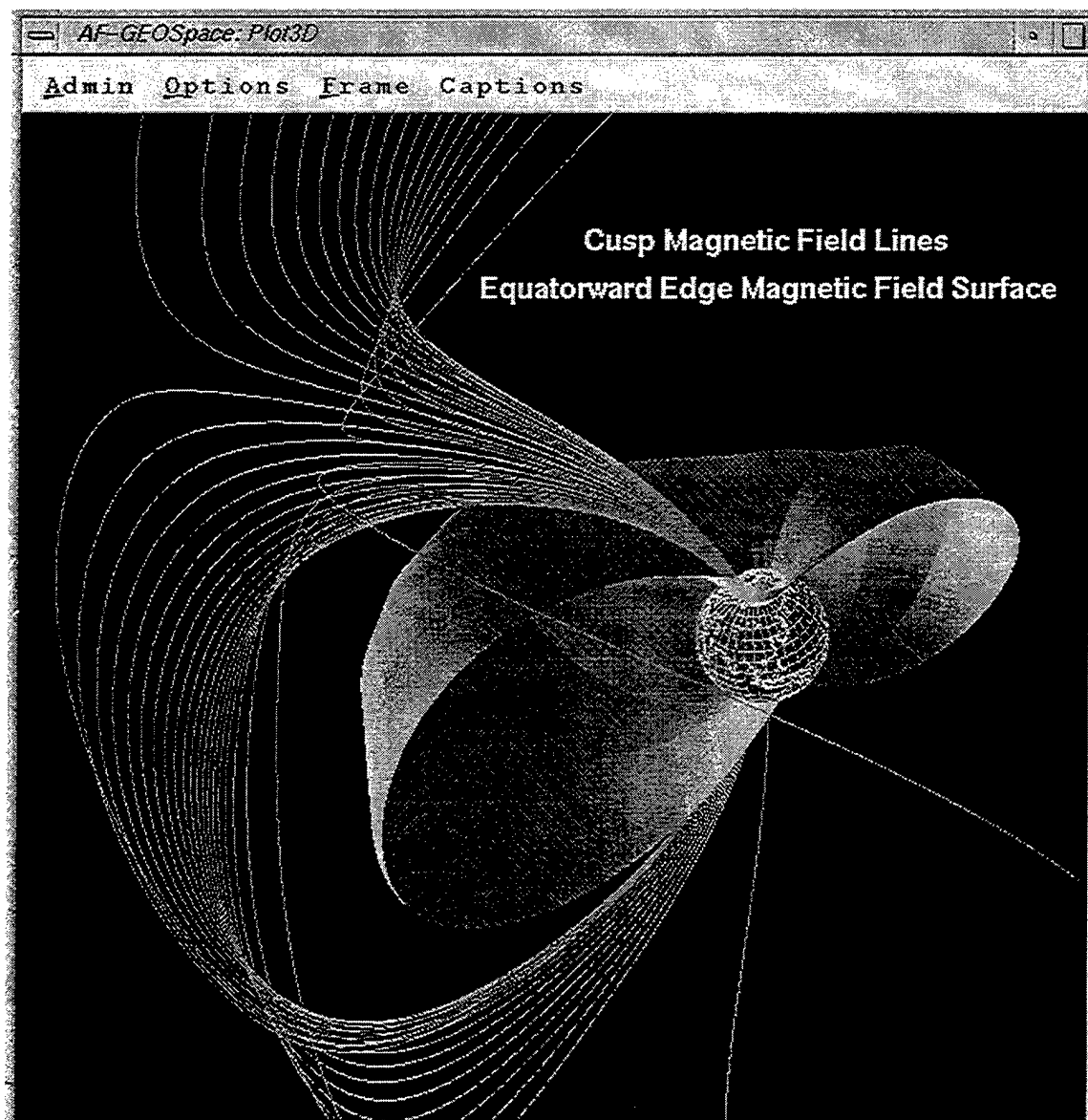


Create and plot a data set showing the equatorward boundary of the aurora mapped out along magnetic field lines,

- Choose *Modules* from the Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click twice on *AURORA* in the *Available Science Modules* list. A second *AURORA* object will appear the *Active Science Modules* list and a set of *AURORA* Options will appear in the Environment Window.
- Under “Generate” check the *Eq Edge* option and uncheck the *Gridded data* option. Select the *IGRF(1945-2000)* “Internal B-Field” option and the *Tsyganenko '89* “External B-Field”

option. Choose the *Kp Only* option in the Tsyganenko '89 Window that appears and close it. Leave the "Equatorward Edge Parameter" and "Model" sections set at their default values.

- Click the *Run Model* button at the bottom of the Environment Window to generate and map the equatorward boundary field lines. The *Model Status* box will show the global parameters used and indicate that the model is ready after the red Wait Window vanishes.
- Select *Graphics* from the *Modules* menu and turn off the Hilmer-Voigt (yellow) and Olson-Pfizer (white) cusp flux tubes by clicking the *ON/OFF* button while the appropriate FIELD-LINES Graphics Objects are highlighted in the *Active Graphics Modules* list.
- Click on *FIELD-LINES* in the *Available Graphic Modules* list that appears. A fourth FIELD-LINES object appears in the *Active Graphics Modules* list and a set of Field-Lines Options appears.
- Click the *Data* button, slide down to the second AURORA listed, and select *Mapped Eq. Edge*. Click on the window background to register your choice. Click on *Filled Surface* under "Plot Type" and remove the check mark from the *Field Lines* option. Click on the *PLOT3D* line of the *Display In* box to view the magnetic surface corresponding to the auroral electron equatorward boundary in the Plot3D Window.
- To create a cross section view of the equatorward boundary surface click on the *Clipping* button in the FIELD-LINES Graphical Object. Click *On* and then move the *Rotate-Y* slider to 319 and the *Translate-X* slider to 1.0.
- To reproduce the figure on the next page, go to the Plot3D Window *Options* menu and turn off the *Show Color Bar* option. Select the *Show View* option from the *Admin* menu and set *Latitude* = 43, *Longitude* = 111, *Twist* = 350, *Scale* = 0.34, *Zoom* = 2.9, *Translate X* = -1.0, *Translate Y* = -0.2, and *Translate Z* = -0.2. Close the Viewer Window. Mouse buttons can also be used to achieve this view (select *Show Hints* from the *Options* menu in the Plot3D Window).
- To create the captions, go to the *Captions* menu of the Plot3D Window and select the *Caption Text* option. In the Caption Window that appears, enter "Cusp Magnetic Field Lines" in the "Caption 1" text box (and set "x"=0.55 and "y"=0.90) and enter "Equatorward Edge Magnetic Field Surface" in the "Caption 2" text box (and set "x"=0.45 and "y"=0.85). Hit the *Update* button and close the window. Check the *Show Captions* options from the *Captions* menu and the two captions will appear. To increase the font size, select the *Set Font* option from the *Captions* menu and select the *18 Point* size *Helvetica* font.
- Another way to visualize field lines attached to features of the two-dimensional particle precipitation maps created by the AURORA Module is to run AURORA on a three-dimensional grid. This can be accomplished by using the Grid Tool to specify a non-zero interval with greater than one point for the radius coordinate. Plotting the resultant AURORA dataset as an Isocontour in a Plot3D Window will reveal the magnetic surface corresponding to a specific flux level contour in the original two-dimensional map. Note: Be sure to change the minimum Latitude value of the grid to a small number (e.g., 1 degree) when running AURORA in three dimensions to avoid unphysical jumps in the Isocontour plots.



This completes the Example of The Magnetospheric Cusp and Auroral Equatorward Boundary.

8) Auroral Radar Clutter

The following example demonstrates the use of the DMSP-SPECTRA Data Module, the equatorward edge mapping capabilities of the AURORA Science Module, the radar fan portion of the EARTH Graphics Module, and a variety of visualization tools.

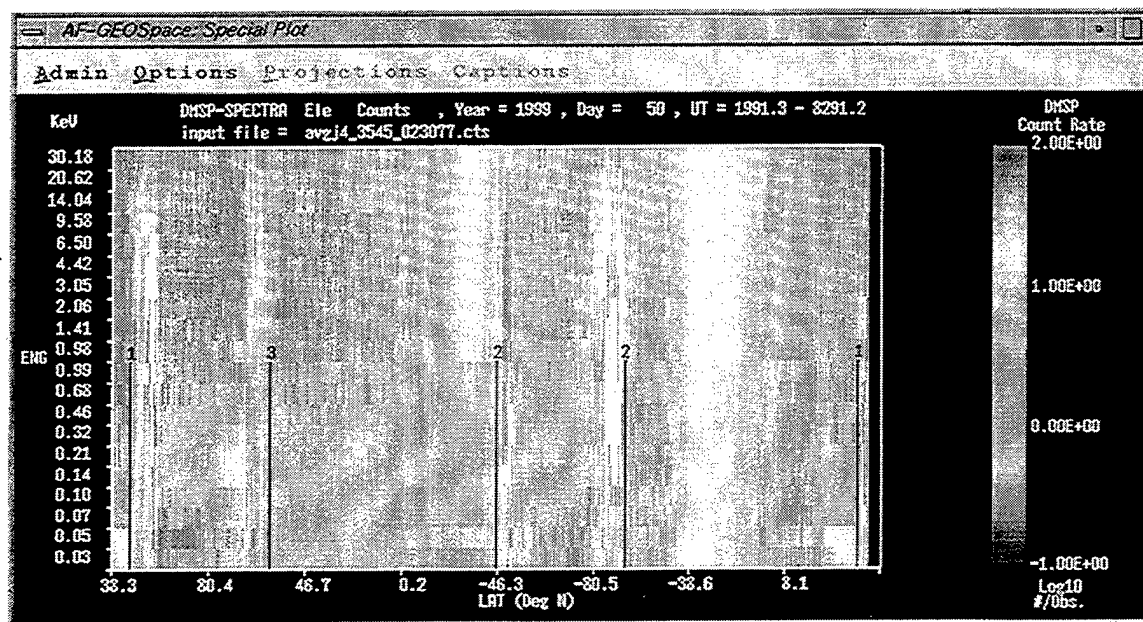
Goal: Backscatter reflections from electron density irregularities aligned along the Earth's magnetic field lines can contribute to radar clutter at high latitudes and thus degrade radar performance. Radar clutter is concentrated at points in space where the radar is propagating perpendicular to the local magnetic field direction. Precipitating auroral electrons following magnetic field lines contribute to these electron density irregularities. The goal of this example is to determine the position of the equatorward edge of the auroral electron precipitation (directly from DMSP data files) and map out the magnetic field line surface defining where radar clutter might first be experienced by radar penetrating into auroral latitudes. Specifically, we will determine a Kp-based statistical picture of where aurora might interfere with radar operations on Cape Cod, MA and in Shemya, AK.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- At the top of the Environment Window, edit the time input text fields to read "Year"=1999, "Day"=50, "UT"=00:36 then click on the *Globals* button and select the *Recent* option. The Kp(=5), SSN(=122), F10.7(=164), and Ap(=-1, meaning no data) for that time will appear.

Display DMSP electron spectral data and view details about equatorward boundaries observed,

- In the Menu Bar at the top of the Environment Window, click on *Modules* and select *Data*. *Available Data Modules* and *Active Data Modules* lists will appear. Click on *DMSP-SPECTRA* from the *Available Data Modules* list. A DMSP-SPECTRA object will appear in the *Active Data Modules* list and a set of DMSP-SPECTRA Options will appear in the Environment Window.
- Click on the *Run Model* button at the bottom of the Environment Window and a Spectra File Selection Window will appear. Enter "\$AFGS_HOME/PLGS/examples/case/*" in the "Filter" text window and click on the *Filter* button. Select the file name "case_99_050_01991_3545" and click the *OK* button at the bottom of the selection window. A Special Plot Window and a DMSP-SPECTRA Case Info Window will appear after the red Wait Window vanishes.
- The Special Plot Window shows DMSP satellite electron counts for a range of energies as a function of Universal Time (UT). Equatorward edge boundaries determined by the automated algorithm are marked by black vertical lines labeled with quality flag numbers (1-4) indicating the overall quality or statistical significance of the boundary (1 is best).

- Click on the *Plot Options* button in the Environment Window and a Spectra Plot Options Window appears that allows you to adjust the attributes of the Special Plot Window. Change “X axis” selection from *UT* to *Lat* and click the *Plot Update* button in the upper right-hand corner of the window. The x axis in the Special Plot Window will now read “LAT (Deg N)”. The Spectra Plot Options Window can be closed using the pulldown menu from the upper left corner. The Special Plot Window should now match the following figure.



AF-GEOSpace: DMSP-SPECTRA Case Info

Admin

Equatorward boundary info for file avgj4_3545_023077.cts

case	UT	MLT	MLAT	Kp	Qe	flag
1	2149	74132	58.5	6.50	12.65	1
2	3301	34452	58.7	9.10	17.85	3
3	5181	26862	-61.0	5.52	10.69	2
4	6257	78022	-57.0	6.11	11.87	2
5	8205	71141	58.8	7.61	14.87	1

- The DMSP-SPECTRA Case Info Window (shown above) lists the details associated with each of the black vertical lines marked on the spectral plot above with “case” numbers assigned in order of the UT of the measurement. The MLT, MLAT, effective Kp, Qe, and the quality flag for each case of equatorward boundary are listed. The effective Kp is derived from the boundary MLT and MLAT.

View the DMSP orbit path where the observations were made,

- From the Menu Bar at the top of the Environment Window, click on *Windows* and select *Create 3D Plot*. A Plot3D Window for displaying 3D gridded data sets will appear.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.
- Select *EARTH* from the *Available Graphics Modules* list. An EARTH object will be added to the *Active Graphics Modules* list and a set of EARTH Options will appear in the bottom of the Environment Window.
- Under “Outline Detail”, select *Geographic Bndys* and *Locations*. Under “Grid Options”, select *Lat/Lon Grid*. Note that the less detail shown on the Earth, the faster the response for its 3D manipulation.
- Click on *PLOT3D* in the *Display In* list at the bottom of the Environment Window and a globe will appear in the Plot3D Window. Remove the Plot3D Window color bar by choosing the *Options* pulldown menu of the Plot3D Window and remove the check mark from *Show Color Bar*. The Earth’s size can be scaled in the Plot3D Window using the middle mouse button. With the cursor in the Plot3D Window, depress the middle button and draw the mouse toward yourself.
- To see the DMSP orbit path, scroll down the *Available Graphics Modules* list and click on *SATELLITE*. A SATELLITE object will be added to the *Active Graphics Modules* list and a set of Satellite Options will appear in the Environment Window.
- Click the *Orbit* button and select *DMSP-SPECTRA*. Click the *Label* button and select *Sat. Name* and check-off *Pop Marker* so that the satellite label remains visible at all times. Click on *PLOT3D* in the *Display In* box. The DMSP satellite orbit path associated with the DMSP-SPECTRA data appears in the Plot3D Window.
- Click on the *Marker* button and “Marker Parameters” appear at the bottom of the Environment Window. Use the *Radius* slider to reduce the satellite marker size to 0.05 Re. Click on the *Windows* button to remove the “Marker Parameters” options. Use the *Satellite position (%)* slider to move the satellite along the orbit path corresponding to the spectral plot.

View the equatorward auroral boundaries determined from the DMSP data,

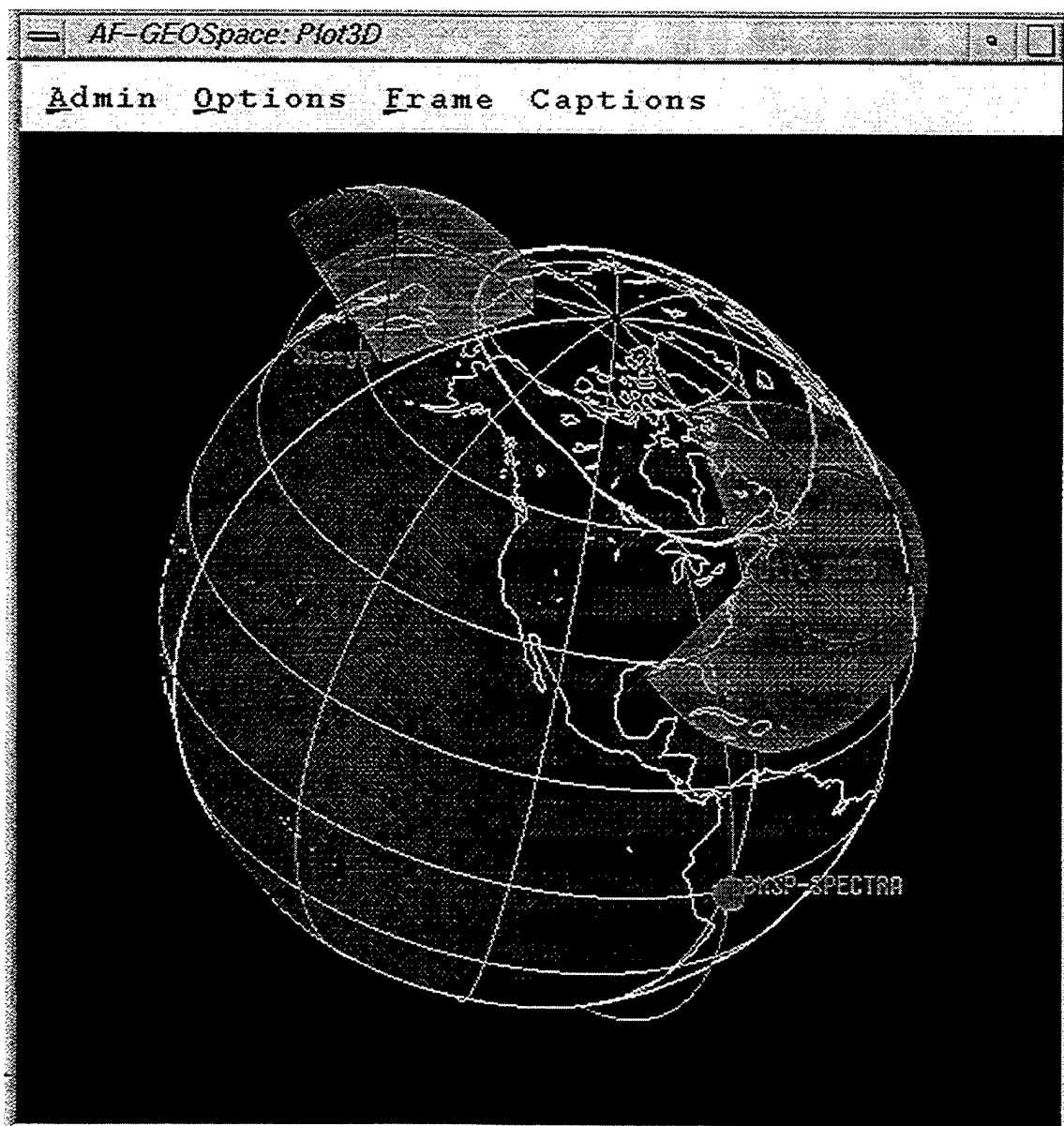
- To display the equatorward auroral boundary lines, scroll up the *Available Graphics Modules* list and select *FIELD-LINES*. A FIELD-LINES object will be added to the *Active Graphics Modules* list and a set of Field-Lines Options will appear in the bottom of the Environment Window.
- Click the *Data* button and under DMSP-SPECTRA select *Eq. Edge*. Click anywhere on the window background to register your choice. Highlight *PLOT3D* in the *Display In* box and several equatorward boundary ovals will appear in the Northern Hemisphere in the Plot3D Window. Use the first mouse button to rotate the Earth to view the northern hemisphere.

- The lines can be viewed individually by returning to the *Data* button and selecting *Eq. Edge 1* (for case 1 of the text window) or *Eq. Edge 2* (for case 2 of the text window), etc. and clicking on the *Update* button. By looking back in the Special Plot Window we can see that cases 1, 2, and 5 were observed at northern geographic latitudes and cases 3 and 4 were observed in the southern hemisphere. Note that all ovals are drawn in the northern hemisphere, even if the equatorward boundary observations was made in the southern hemisphere.
- Move the *Field Line Width* slider to read “2” and the boundary lines will thicken. Each green oval was generated using a single equatorward boundary observation case as listed in the DMSP-SPECTRA CaseInfo Window. Each oval is anchored using information from one of the observation points listed in the text window. The ovals represent, statistically, the most likely location for the equatorward edge boundary.
- Click on the *Data* button, slide down to the DMSP-SPECTRA, and select *Eq. Edge 1*. Click on the *Update* button and now a single oval corresponding to the effective $K_p=6.50$ of case 1 from the text box is shown.

Create and display radar fans emanating from Cape Code, MA and Shemya, AK,

- In the *Active Graphics Modules* list of the Environment Window click on the *EARTH* entry and the Earth Options we established earlier reappear. Under “Outline Detail” make sure that the *Locations* option has a check mark next to it. Now click on the *Locations* button near the bottom of the window (between the *Colors* and *Emitters* buttons) and a location popup window will appear.
- To set up some new stations for locating our radar fans, click the *Create* button and an add station popup window will appear. Complete the text boxes to read “Label”=Otis ANGB, “Altitude(Km)”=0.0, “Lat(N)”=41.75, and “Lon(E)”=-70.54. Click the *Accept* button and there will now be an Otis ANGB entry in the Stations list with an asterisk preceding it (you may have to scroll down the *Stations* list).
- To setup the second location, click again on the *Create* button in the location popup window and complete the text boxes to read “Label”=Shemya, “Altitude(Km)”=0.20, “Lat(N)”=52.72, and “Lon(E)”=-185.90, and click the *Accept* button. Scroll down the *Stations* list to see the Shemya entry listed (also with an asterisk, which indicates that it is selected for display). Click the *Done* button and the Plot3D Window should now have Otis ANGB and Shemya location markers visible. You may have to rotate the Earth to see these stations.
- To setup an emitter, click the *Emitters* button and click the *Create* button in the emitter popup window that appears. Highlight the **Otis ANGB* entry in the *Emitter Station ID* list and edit the “Emitter Name” text box to read “Otis”, select *Radar* as the “Type”, set “Range (Km)”=4000, set “Azimuth Limits (Deg)” to -12 and +245, set “Elevation Limits (Deg)” to 5 and 60 degrees. Click the *Accept* button and the remaining emitter window will now have an “*Otis ANG-ROtis” entry. Highlight the entry to see details of the emitter. With the Otis entry highlighted, move the *Transparency Alpha Value* slider to read 0.40, hit the *Apply* button to register the Appearance Options selected and the transparent Otis radar fan appears in the Plot3D Window.

- To setup another emitter, click the *Create* button in the emitter popup window. Scroll down the *Emitter Station ID* list and highlight the Shemya emitter station now listed (with an asterisk) as an option. Edit the “Emitter Name” text box to read “Shemya”, select *Radar* as the “Type”, set “Range (Km)”=3000, set the “Azimuth Limits (Deg)” to -101 and +19, set “Elevation Limits (Deg)” to 5 and 60 degrees. Click the *Accept* button and the remaining emitter window will now have an “*Shemy-RShemya” entry. Highlight this entry to see details of the emitter. With the Shemya entry highlighted, move the *Transparency Alpha Value* slider to read 0.40, click the *Color* button and move the *Red* and *Blue* sliders to the far right and the *Green* slider to the far left in the color chooser window. Click *Apply* and OK in the color window. In the emitter window, click the *Apply* button, then the *Done* button in the emitter window. The Plot3D Window should now have a purple radar fan emanating from Shemya AK and a red radar fan emanating from Cape Cod MA as in the following figure.

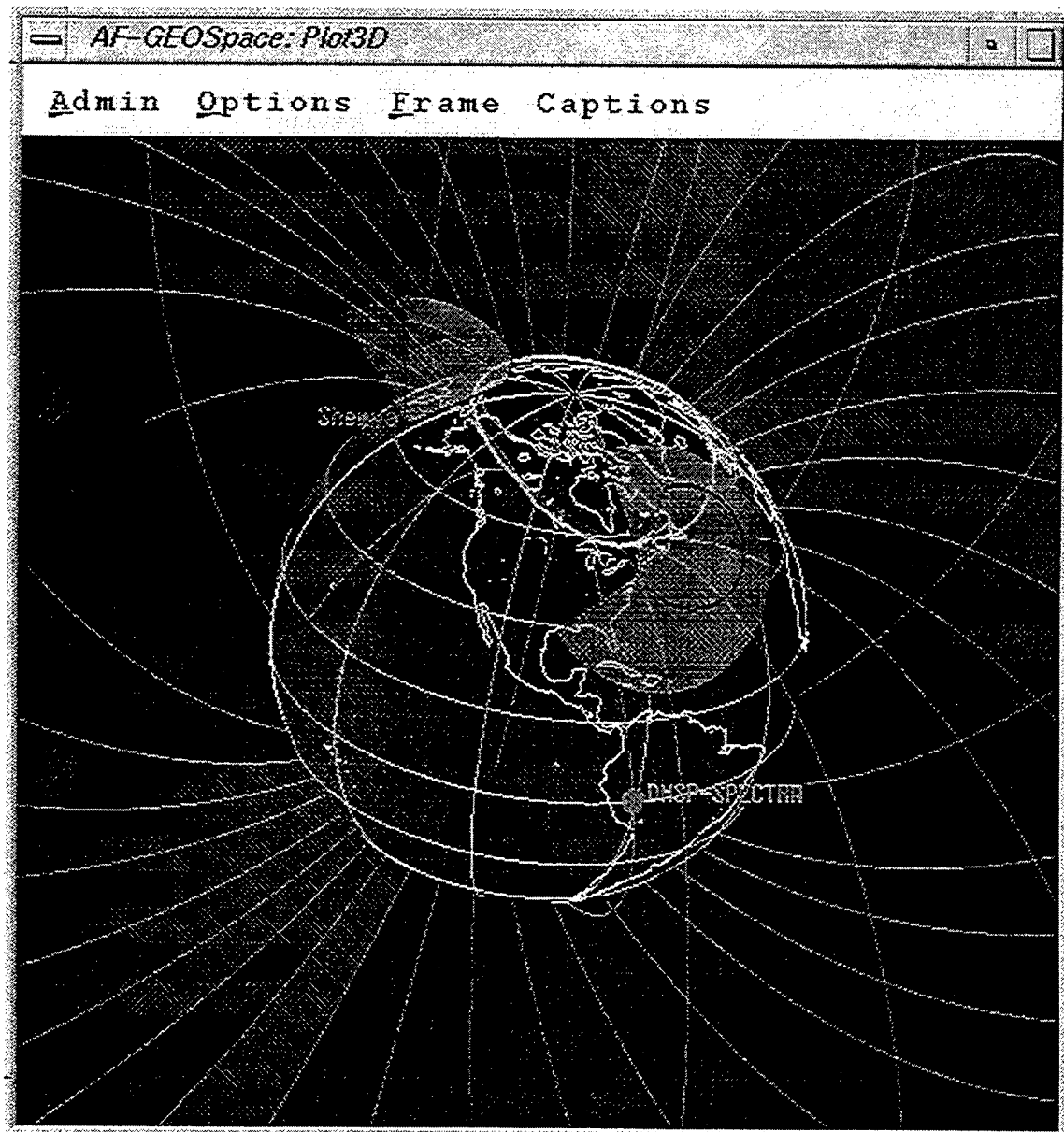


- To replicate the figure above, highlight the SATELLITE entry in the *Active Graphics Modules* list and the Satellite Options we used earlier appear again. By moving the *Satellite position (%)* slider from the extreme left (at 0.000) to extreme right (at 1.000) you can see where the DMSP satellite was as it recorded the data in the Special Plot spectral plot. Set the slider to read approximately 0.85 and use the first two mouse buttons to scale and rotate the image.

Generate the magnetic field line data set corresponding to the DMSP-SPECTRA equatorward edge boundary now displayed in the Plot3D Window,

- Early in this example we set the model time to correspond to the equatorward edge case (1) selected, i.e., “Year”=1999, “Day”=50, “UT”=00:36 (the hour:minute equivalent of the 2149 seconds UT in the text window). Note that the Globals Kp is 5 (see top of the Environment Window) while the effective Kp derived from the DMSP boundary observation is 6.5. These values are, in fact, consistent with each other if we note that the Globals Kp is a 3-hour index while the effective Kp determined using DMSP boundary observations tracks changes on the (~15 minute) time-scales on which the aurora can change.
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Science*. *Available Science Modules* and *Active Science Modules* lists will appear.
- Click on *AURORA* in the *Available Science Modules* list. An AURORA object will be added to the *Active Science Modules* list and a set of AURORA Options will appear in the bottom of the Environment Window.
- To map magnetic field lines emanating from the equatorward edge boundary, under “Generate” check *Eq Edge* and remove the check next to *Gridded Data*. Set “Internal B-Field” to the *Fast IGRF* option. Set “External B-Field” to the *Tsyganenko ‘87* option.
- Under “Equatorward Edge Parameters” select *Use single observation* and *Map from North*. The oval in the Plot3D Window represents case 1. To map magnetic field lines from the statistical equatorward edge position associated with that case, edit the two text boxes in this section of the Environment Window to match the case 1 details listed in the DMSP-SPECTRA Case Info Window, i.e., set “MLT”=20.59 hours and “Observed MLAT”=58.5 degrees. (An equivalent procedure would be to enter the effective Kp from the text window for case 1, i.e., Kp=6.50, in the “Kp” text window at the very top of the Environment Window and instead select *Use Kp* as the Equatorward Edge Parameters options.)
- Note that the Kp value listed at the top of the Environment Window is not used because we are not generating gridded data and have used an observed DMSP boundary crossing point to determine the location of the equatorward edge.
- Click on the *Run Model* button at the bottom of the Environment Window. A red Wait Window will appear temporarily. When the model is complete the Wait Window will disappear and the *Model Status* box will indicate that the “MODEL IS READY AND UP TO DATE.”
- Return to the Menu Bar at the top of the Environment Window, click on *Modules* and select *Graphics*. *Available Graphics Modules* and *Active Graphics Modules* lists will appear.

- Select *FIELD-LINES* from the *Available Graphics Modules* list and a second *FIELD-LINES* object will be added to the *Active Graphics Modules* list. Use the *Data* button to select *AURORA* and then *Mapped Eq. Edge*. Click on the *Update* button to register your choice. Under “Plot Type” check *Field Lines*. Select *PLOT3D* in the *Display In* box and magnetic field lines emanating from along the equatorward edge oval will appear in the Plot3D Window. (Note that the equatorward edge oval can also be plotted using data generated from within AURORA by selecting the *Eq. Edge* data option from the Field-Lines Options instead).



- Note that the radar fans penetrate poleward of the field lines mapped out along the equatorward edge boundary. To see where the radars actually penetrate the field lines carrying the auroral precipitation, check the *Filled Surface* option under “Plot Type”. To make the field line surface more transparent, click on the *Transp.* button and move the *Alpha Value* slider that

appears to a value of 0.30. By rescaling the Plot3D Window you can view the Earth from within the field line surface. Rotating the Earth up and down lets you break through this surface and view the region poleward.

- To replicate the last figure, go to the *Admin* menu of the Plot3D Window and select the *Show View* option. Adjust the sliders in the Viewer Window that appears to read approximately: “Latitude”=28, “Longitude”=261, “Twist”=8.1, “Scale”=4.3, “Zoom”=0.95.

Once again, from this picture we get a rough idea of the radar sweep regions that might contain precipitating auroral electrons (i.e., coming down magnetic field lines) that can interfere with the radar signals. If the same procedure is applied to case 5 of the DMSP-SPECTRA Case Info Window, we would see an even larger auroral oval (effective Kp has increased to 7.61) and thus a larger potential region for radar interference to occur.

This completes the Example of Auroral Radar Clutter.

9) HF Ray-Tracing in the Ionosphere

The following example demonstrates the use of the Parameterized Ionospheric Model (PIM) Science Module, the Ionosphere Analysis/Modeling System (IMAS) 2-D ray-tracing Application Module, and a variety of visualization tools.

Goal: Electron density variations in the ionosphere determine how radio communications signals propagate. Signals tend to bounce off regions where the local critical plasma frequency is greater than the signal frequency (high electron density correlates with high critical plasma frequency). Therefore, an HF signal transmitted from a ground station with just the right frequency can experience multiple “hops” and be received at several geographic locations along its ray path. The goal of this example is to generate ionospheric data sets, including 3D electron density profiles and a 2D map of critical frequencies in the F2 layer (called foF2), and examine how HF rays propagating from ground-based transmitters follow frequency dependent paths, i.e., travel different distances before returning to the Earth’s surface.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: “AFGS”. The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.
- Set the Global Parameters as follows: “Year”=1991, “Day”=187, “UT”=00:00. Click on the *Archive* option of the *Globals* button and the Kp, SSN (sunspot number), F10.7 radio flux, and Ap index corresponding to the specified date and time will be loaded automatically from archived NGDC values (“Kp”=1.3, “SSN”=204, “F10.7”=240.8, and “Ap”=5).

Create PIM Model data sets,

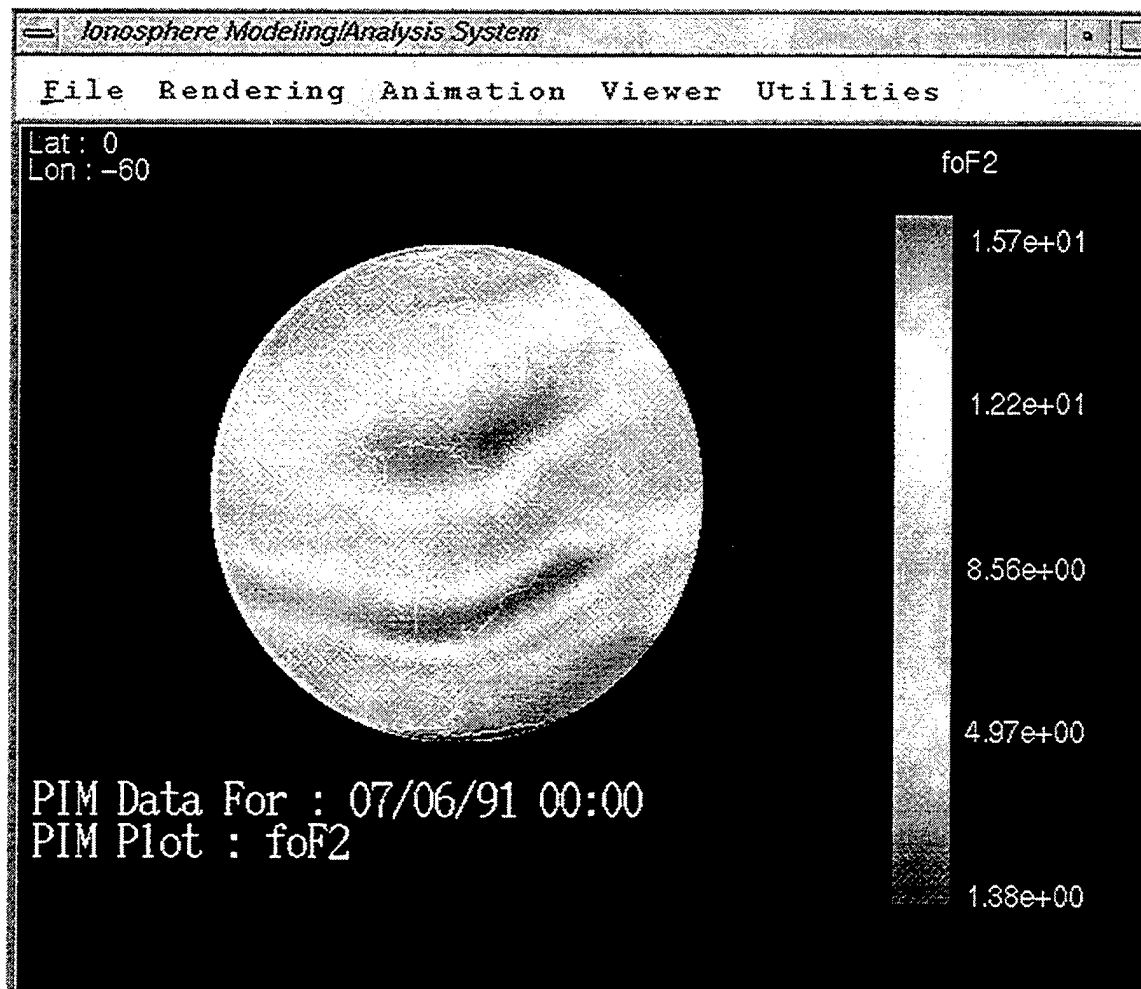
- Choose *Modules* from the Menu Bar and select *Science* from the options. *Available Science Modules* and *Active Science Modules* lists will appear.
- Scroll down in the *Available Science Modules* list and click on *PIM*. A PIM object will be added to the *Active Science Modules* list on the right and a set of PIM Options will appear in the bottom of the Environment Window.
- Click on the *IMF By* menu button and select *Positive*. Leave the other options at their default values. These settings will run PIM with no normalization under conditions with a positive Interplanetary Magnetic Field (IMF) By component and negative Bz component. The default grid is set to 2° latitude x 5° longitude, the resolution most compatible with the ray-tracing program. The PIM model results are written to the default output file named “pim_pud.out”.
- Click on the *Run Model* button in the bottom left of the Environment Window. When complete, the Wait Window disappears and the *Model Status* box will indicate the Global Parameters used. At this resolution, PIM can take several minutes to run on the SGI R4000 CPU.

Plot the PIM critical frequency profile in the F2 layer (called foF2),

- At the top of the Environment Window, click on *Modules* and select *Applications*. *Available Application Modules* and *Active Application Modules* lists will appear.
- Scroll down the *Available Application Modules* list and select *IMAS-APP* (the PIM Users Display). An IMAS module will be added to the *Active Application Modules* list and a PIM Users Display panel will appear in the bottom of the Environment Window.
- Click on the *Run Model* button in the bottom left of the Environment Window and an IMAS window will appear with an image of the Earth.
- Under the *File* column in the menu bar of the IMAS window, select the *Open PIM Data...* option. A list of files in the current working directory will be displayed. Click on the file name "pim_pud.out", then click the *OK* button at the bottom of the File Selection Window. PIM data will be read into the IMAS application and the selection window will disappear when the transfer is complete.
- Select the *Utilities* column in the menu bar at the top of the window. Slide down to the *PIM Global Plots* option. In the PIM Global Displays Window that appears, click on the *foF2* option, the *Show Day/Night* option, and change the *Transparent Value* slider to 0.75. Close the PIM Global Displays Window using the tab pulldown menu. Units of foF2 are MHz.
- Return to the menu bar at the top of the IMAS window and choose the *Viewer* column. Click the heads-up display (*Show HUD*) option. By using either the *Location* option in the *Viewer* column or the left mouse button, rotate the Earth until the observation point is above 0° latitude and -60° longitude. Using either the *Move* option in the *Viewer* column or the right mouse button, raise the Earth until it is above the heads-up display data. The IMAS window should now resemble the figure on the next page.

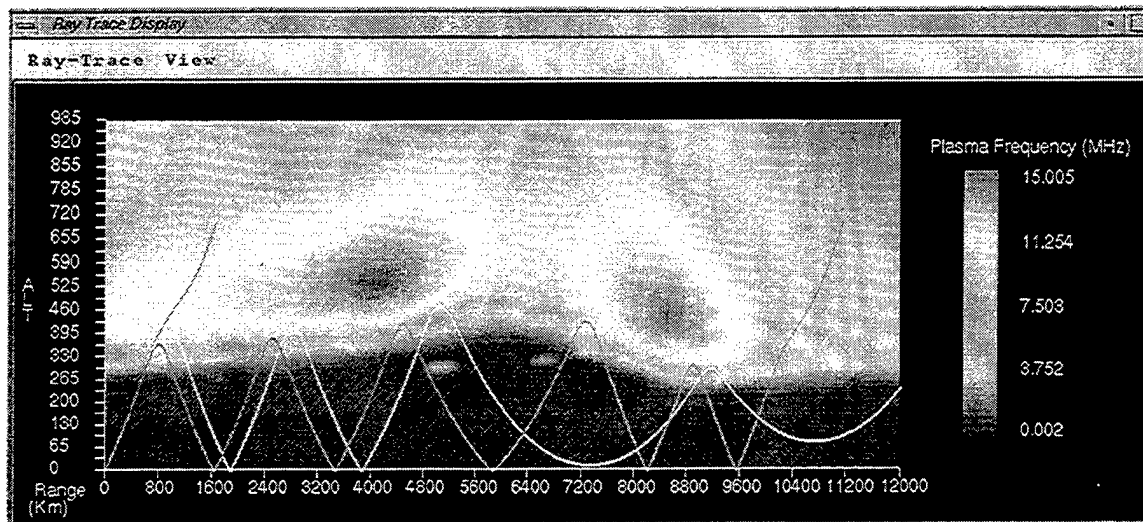
Plot HF Ray-Traces,

- Return to the IMAS menu bar and select the *Utilities* column. Slide down to *Ray-Trace*. A new Ray-Trace Display Window will open.
- In the menu bar at the top of the Ray-Trace Display Window choose the *Ray-Trace* column and select the *Transmitter* option. A Set Transmitter Location Window will appear. Select *Bangor, ME* from the list of pre-set locations on the right side of the window. The latitude and longitude of Bangor, ME will appear in the appropriate boxes. Click on the *Apply* button in the lower left hand corner of the window to register your selection and remove the window.
- Return to the Ray-Trace Display Window menu bar and select the *Freq/Elev* option in the *Ray-Trace* column. A Set Ray Parameters Window will appear. Click on the *Plot Ray* button in the Set Ray Parameters Window. A two-dimensional altitude versus range slice of the PIM generated electron density levels will appear in both the Ray-Trace Display Window (2D) and the IMAS Window (3D).



- Returning to the Set Ray Parameters Window, set the *Freq(MHZ)* parameters to go “From” 16 to 26 with a “Step” of 5.0. This can be done by clicking on the appropriate box and either typing or using the slider above the boxes. To select an elevation angle of 20 degrees for the transmitting antenna, under “Elev(deg)” set the “From” option to 20 by either typing in the box or using the slider once the box is selected. Click on the *Plot Ray* button to compute and plot the chosen rays in the Ray-Trace Display Window.
- A list of the rays created and plotted can be obtained by clicking on the *Plot List* button in the Set Ray Parameters Window. In the *Displayed* list, highlight the “Freq: 21 Elev:20” entry to color that ray white in the Ray-Trace Display Window. Use the *Dismiss* button to close the Set Ray Parameters Window. It can be seen that the 16 MHz ray bounces regularly in the Earth-ionosphere waveguide, the 26 MHz ray escapes the ionosphere, and the 21 MHz ray (white) enters a “whispering gallery mode” whereby it remains trapped in the ionosphere but does not return to the ground (barely) after the second hop. The Ray-Trace Display Window should now resemble the figure on the next page.
- The ray-traces can also be displayed in the 3D IMAS Window. Choose the *Rendering* column in the menu bar at the top of the IMAS window. Selecting the *Visible Rays* option will super-

impose the ray traces on the electron density slice. Choose the *Rendering* column again and select the *Ground Points* option to highlight in green the points at which the rays touch the Earth once they have left the transmitter. If you rescale the Earth in the IMAS window (use the center mouse button), you can see that the 16 and 21 MHz signals travel from Bangor ME and touch down once in the Atlantic Ocean and again near the northern coast of South America. This last feature is easier to see if you choose the *Rendering* column and turn off the *Iono-*
sphere option.



- Note that the basic physical quantities calculated using the PIM science module can also be viewed in the Plot2D and Plot3D Windows using graphics modules such as COORD-SLICE, but the IMAS application is necessary to complete ray traces, etc.

This completes the Example of HF Ray-Tracing in the Ionosphere.

10) Outer Zone Energetic Electron Dynamics

The following example demonstrates the use of the High Energy Electron Monitor (HEEM) Data Module.

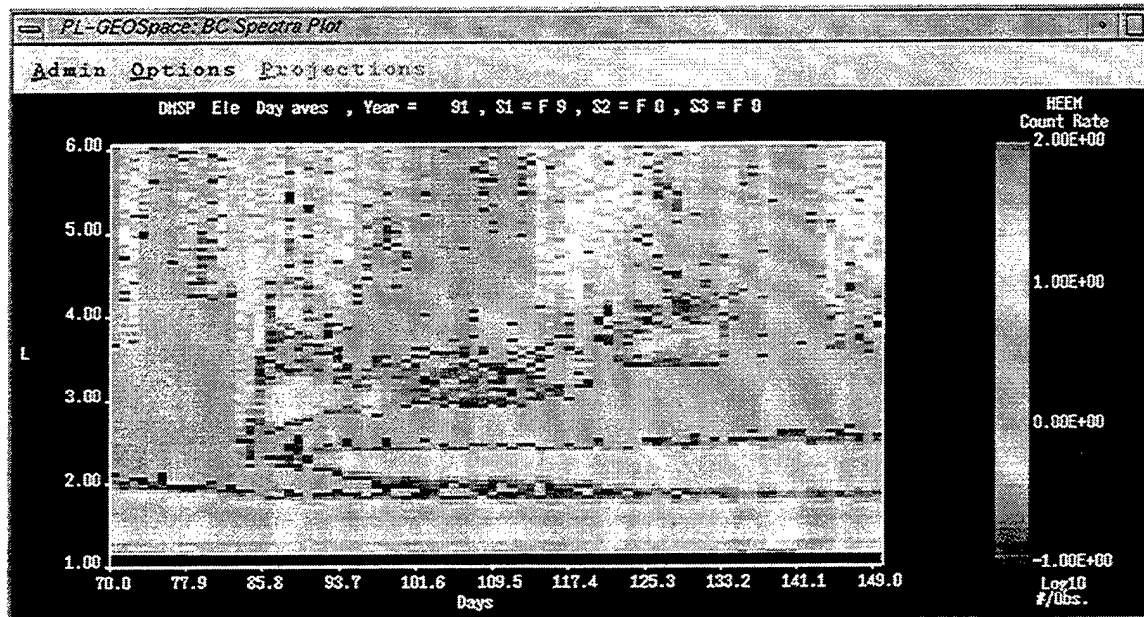
Goal: The HEEM Data Module provides the capability to qualitatively monitor the activity of radiation belt MeV electrons in near real-time using data from the DMSP satellites. This is possible because, while the DMSP instrument nominally measures keV particles, it was discovered that one source of background contamination was due to radiation belt MeV electrons precipitating at the lower DMSP altitudes. The goal of this example is to compare the activity level of the MeV electrons in the outer zone of the radiation belts observed during a period near solar maximum with the activity observed during a period of recurring high-speed solar wind stream events.

- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and the Environment Window will appear.

Plot daily averages of MeV outer zone electron activity during the maximum of Solar Cycle 22,

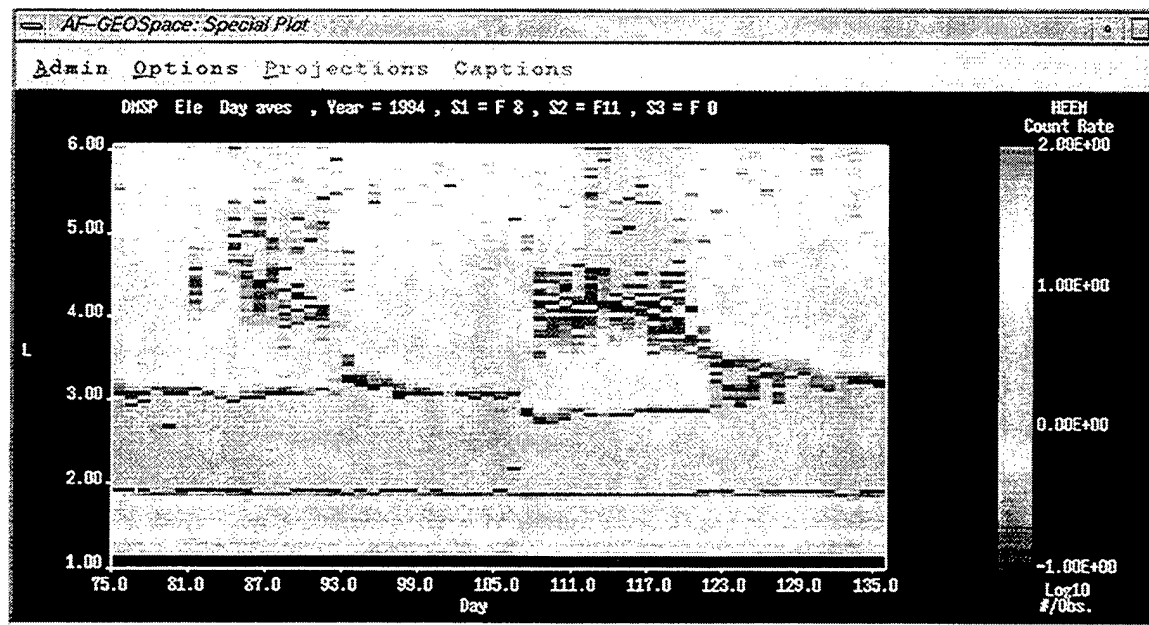
- Set the Global parameters as follows: "Year"=1991, "Day"=70, and "UT"=12:00. Click on the *Globals Archive* button to automatically load archived NGDC parameter values ("Kp"= 2, "SSN"=167, "F10.7"=221.9, and "Ap"=7). These parameters are typical of solar maximum.
- Choose *Modules* from the Menu Bar at the top of the Environment Window and select the option *Data*. *Available Data Modules* and *Active Data Modules* list will appear.
- From the *Available Data Modules* list, select the *HEEM* option and a HEEM module will be added to the *Active Data Modules* list and a set of HEEM Options will appear in the Environment Window.
- Under High Energy Electron Monitor Options, set the "Year" parameter to 1991 and leave all other parameters set at their default values. Click on the *Plot Options* button and a plot options window will appear. Change the "X Days Min" value to 70 and "Max" value to 149. Leave the other parameters at their default values and close the plot options window using the pulldown menu at the upper left.
- Return to the Environment Window and click on the *Run Model* button. After retrieving and processing the data, HEEM will generate a HEEM 2D display window with a color intensity plot of the data as a function of day and L-shell that should resemble the figure on the following page.
- The period displayed represents an extremely active period. Near the start of the period the MeV electrons are relatively benign. On day 83 (24 March), a major injection occurred which produced the long lasting electron (and proton) belt between L-values of 1.8 and 2.5 Re. It

also produced MeV electron populations over the region from below an L-shell of about 3 out to geosynchronous altitude. On about day 115 another event occurred that initially brought particles in to an L-shell value of 4 and later to 3.5 Re. An event near day 135 dumped these trapped MeV electrons quite rapidly, leaving the region from above an L-shell of 2.5 Re relatively free from MeV electrons for the next few days before the next injection event occurred. This plot shows that depending on the size of the event, MeV electrons can be rapidly injected and trapped almost anywhere inside of geosynchronous for long periods and slowly diffuse away, or be rapidly removed during subsequent events.



Plot daily averages of MeV outer zone electron activity as computed by HEEM during a high-speed solar wind stream,

- Return to the *Available Data Modules* list and click twice on *HEEM* and a second HEEM object will be added to the *Active Data Modules* list. A set of HEEM Options will appear in the Environment Window.
- This time, in the text box just above the *Mode* button, set the “Year” parameter to 1994 and leave all other parameters at their default values.
- Click on the *Plot Options* button and a plot options window will appear. Change the “X Days Min” value to 75 and “Max” value to 135. Leave the other parameters at their default values and close the plot options window. Note that HEEM will search for the appropriate data files in the directory that is set by the environment variable *PLGS_BCDMSP_DATADIR*.
- Return to the Environment Window and click on the *Run Model* button. After retrieving and processing the data HEEM will generate a HEEM 2D display window with a color intensity plot of the data as a function of day and L-shell that should resemble the figure at the top of the following page.

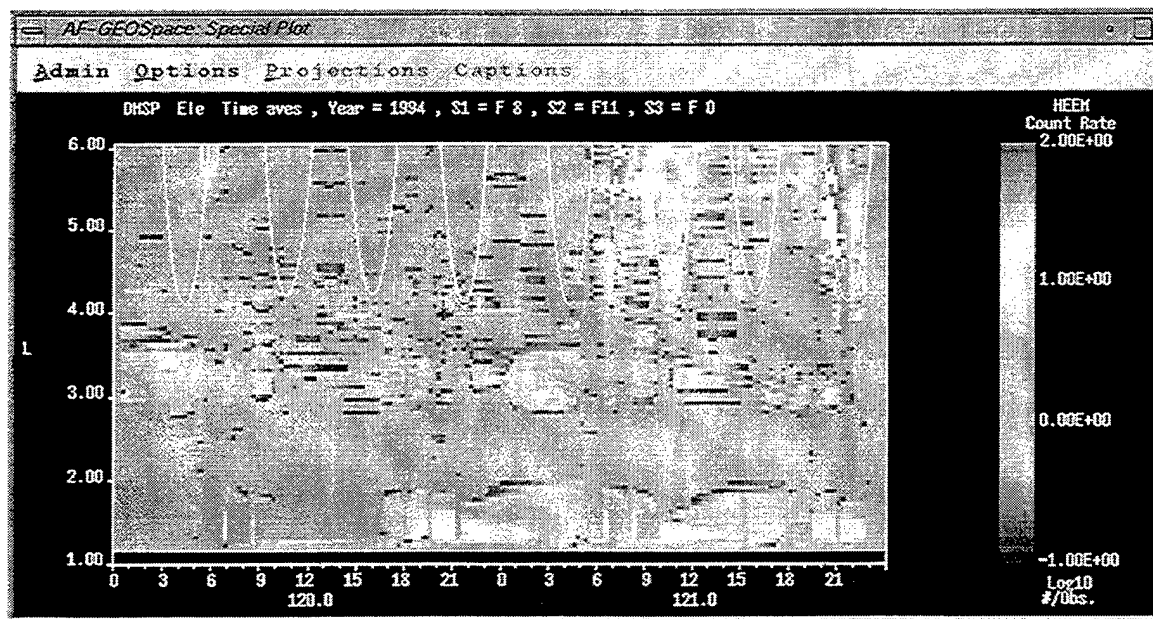


- The period displayed in the figure above represents a very active period containing recurring high-speed solar wind streams associated with the 27 day solar rotation. On both days 92 and 121, the solar wind speed jumped from approximately 400 to 800 km/s following the arrival of a shock. In each case, MeV electrons are seen to increase above the L-shell of 4.5 Re and penetrate to almost an L-shell of 3 Re. For the majority of the interval there are no MeV electrons but some scattered occurrences of 30 keV electrons. It is in conjunction with these MeV electrons, that extend out to geosynchronous and are generated by the passage by Earth of a high-speed solar wind stream, that certain spacecraft started experiencing anomalies (most probably due to dielectric discharging).

Plot a Pass-by-Pass record of outer zone electron activity that covers both the day before and the day after the arrival of a high-speed solar wind stream event and include a satellite.

- Before regenerating the HEEM output we will generate a GPS satellite orbit that regularly passes through the electron radiation belt. From the *Modules* Menu bar select *Applications* and an *Available Application Modules* List will appear. Scroll down and select SATEL-APP. An Ephemeris Data Window will appear and a SATEL-APP module will be added to the *Active Applications Modules* list.
- In the "Element Type" section, click on the *From File* button. A list of satellite orbit elements from the currently chosen file will appear in the middle of the window. Click on the *Select File* button and a list of directories and files will appear in a pop up window. In the "Filter" text box type "\$AFGS_HOME/PLGS/examples/elements/*" and click the *Filter* button at the bottom of that window. In the updated *Build list from file* list, highlight the file "gps_heem.ele" and click the *OK* button. This file contains orbit elements for a typical GPS satellite that will be valid for days 120 and 121 of 1994 (30 Apr - 01 May 94). Highlight the *GPS* entry in the *Current Element File* list and a popup window will detail the GPS orbit elements. Close this small App Window.

- In the lower part of the Environment Window, edit the "T_start" text box to read "04/30/94 00:00:00" and edit the "T_stop" text box to read "05/01/94 24:00:00". Click the *Run Model* button to create the SATEL-APP orbit data set. The Wait Window will vanish and the *Model Status* box will be updated when the orbit has been generated.
- Select *Modules* from the Menu Bar and select *Data* from the options. From the *Active Data Modules* list that appears, highlight the second HEEM object (if it is not already highlighted) that was set up for the 1994 interval. Use the *Mode* button to select the *Pass by Pass* option and the *Orbit* button to select the *GPS* option. Set "Background Interpolation" toggle to *on*.
- Click on the *Plot Options* button and a plot options window will appear. Change the "X Days Min" value to 120 and "Max" value to 121. Leave the other parameters at their default values. Click on the *Plot Update* button. After the Wait Window disappears, close the plot options window.
- Return to the HEEM Options in the Environment Window and move the orbit slider (to the right of the *Orbit* button) to the value 0.600. The HEEM 2D display window should resemble the following figure.



- The HEEM output now shows what would be seen in near-real time from the individual DMSP passes. With a GPS satellite orbit imposed on the plot, it can be seen that GPS cuts through a region of enhanced MeV electrons after hour 6 of day 121. The solar wind velocity increase and density pulse, associated with these energetic particle increases between L-shell of 4 to 6, arrived very early that same day. If we recognize that deep dielectric charging can be a cumulative effect, depending on the properties of the particular satellite and the ambient environment, and if the satellite is prone to spacecraft charging anomalies, then a history can be developed to determine the amount of time the spacecraft has to be in a high energy electron environment before anomalies would occur. The electrons between L-shells of 4 and 6 in

the first portion of the display seem to be spotty, as do the protons in the inner belt. This is due to the location of the DMSP passes in the longitude quadrant containing the South Atlantic Anomaly. The further away from the anomaly, the fewer the energetic particles that will be measured. This does NOT mean there are no energetic particles for that pass - just that DMSP can't see them. Only if a dropout continues for several passes can you be sure that the particles are gone.

This completes the Example of Outer Zone Energetic Electron Dynamics.

11) The Energetic Solar Event of 20 February 1994

The following example demonstrates the use of the Interplanetary Shock Propagation Model (ISPM), Shock Time of Arrival (STOA), and Proton Prediction System (PPS) Science Modules.

Goal: High speed interplanetary shocks originate near the Sun's surface and propagate out into the solar system to disrupt the character of the nominally steady solar wind. Large shocks that hit the Earth's magnetosphere can drastically change the near-earth particle and electric and magnetic field environment and affect the operation of man-made systems. Energetic protons, also originating with solar disturbances, arrive on much shorter time scales and can penetrate deep into the near-earth environment and adversely affect both instruments and biological systems. The goal of this example is to investigate the forecasting capabilities of ISPM, STOA, and PPS using observations of the energetic solar event of 20 Feb 94 and subsequent terrestrial effects. The energetic solar event involved a disappearing filament and an M4/3B flare at 0104UT on 20 Feb 94. This event was responsible for enhanced levels of energetic protons observed by the GOES satellite at geosynchronous orbit and is believed to have caused a CME/shock that arrived at the Earth the next day. All input data have been taken from the NOAA Solar-Geophysical Data Preliminary, Prompt, and Comprehensive Reports.

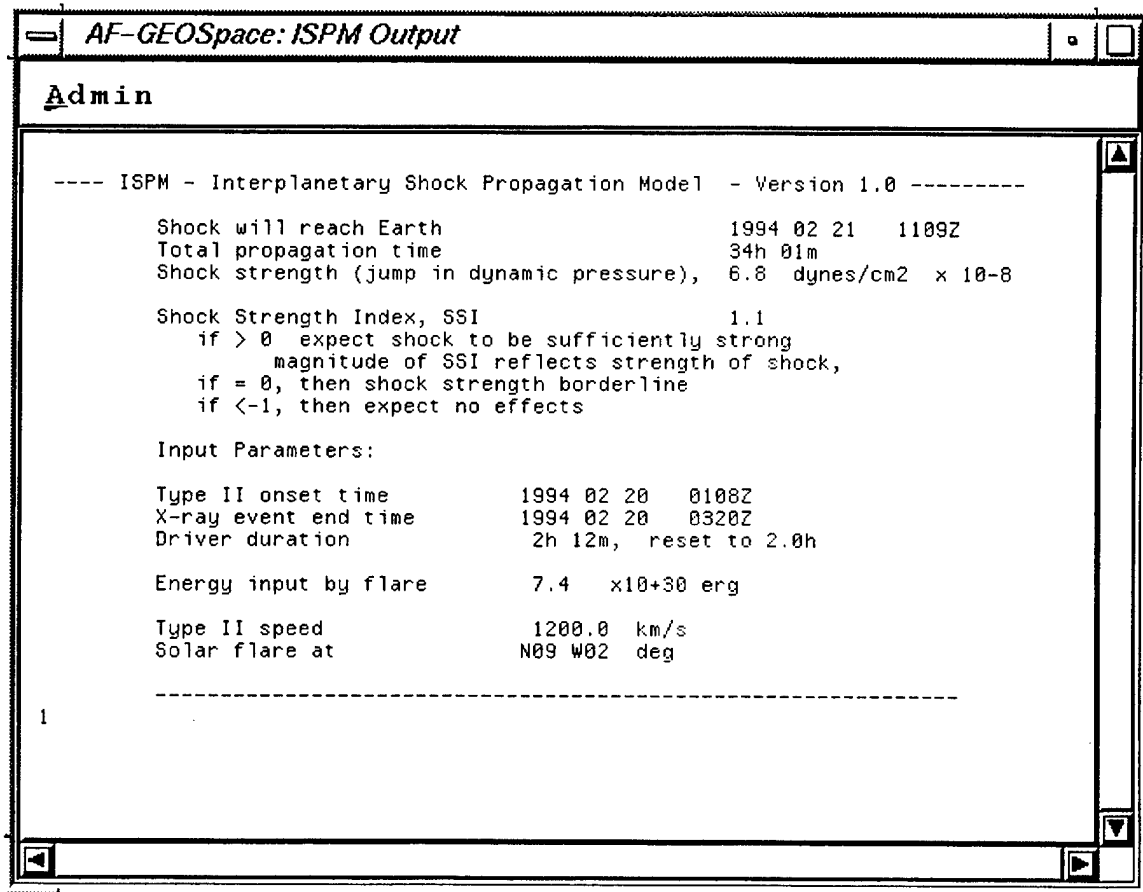
- Initiate AF-GEOSpace from the UNIX prompt by typing the command: "AFGS". The Welcome Window will appear. Ignore the warnings that appear in the standard output window.
- Click on *GEOSPACE: STATIC* in the *Available Environment Modules* list. A *GEOSPACE: STATIC* module will be added to the *Active Environment Modules* list and Environment Window will appear.
- Set the global time parameters to match the observed solar flare time, i.e., set "Year"=1994, "Day"=51, and "UT"=01:04. Click on the *Globals Archive* button at the top of the Environment Window to automatically load the appropriate parameters from the NGDC archive ("Kp"=4.7, "SSN"=16, "F10.7"=105.2, and "Ap"=39). None of these global parameters are used as inputs for this example.

Run the ISPM and display text results,

- From the *Modules* menu at the top of the Environment Window, select the *Science* option. *Available Science Modules* and *Active Science Modules* lists will appear.
- Scroll down the *Available Science Modules* list and click on *ISPM*. An ISPM module will be added to the *Active Science Modules* list and a set of ISPM Options will appear in the Environment Window.
- Under "Specify Event Duration", select *X-ray Levels* option. We will use the GOES 7 1-8 Angstrom X-ray data to determine the duration of the event. Under "Event in the previous 24 hours?," leave this input at its default *No* value as there were none.
- Both Palehua and Learmonth RSTN sites observed Type II radio bursts for this event with estimated shock speeds of 1000 km/s and 1400 km/s, respectively, starting at 0108UT. An H-

alpha flare of magnitude 3B was observed on the solar surface at N09 and W02 by Learmonth at 0138UT and lasted for 90 minutes. Given this data, edit the "Event onset time" text box to read "02/20/94 01:08", set "Flare lat (deg N)"=9, and "Flare lon (deg W)"=2. Assume the shock velocity to be the average of the two observations and set "Type II speed (km/s)"=1200.

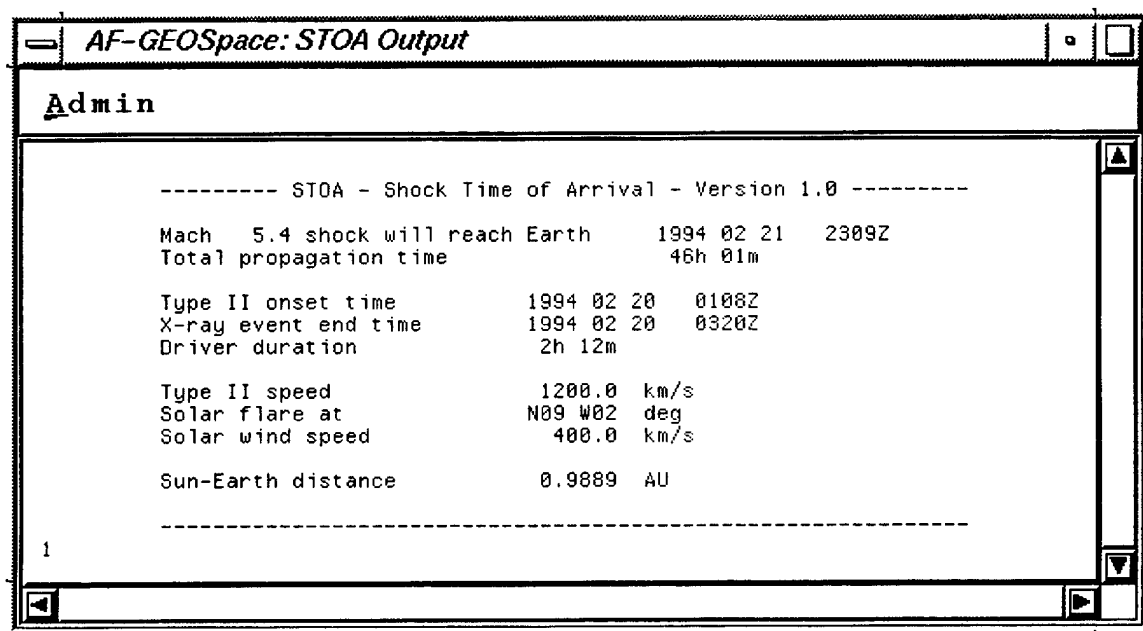
- Examining the GOES 7 X-ray data in the 1-8 Angstrom band, the background classification before the event was approximately B2.0 and the classification of the peak of the event was M4.0. Enter "Backg. Class"=B2.0 and "Peak Class."=M4.0. Click in the decay time text box and the label will change to read "Decay time, level=C2.8". Further examination of the GOES data indicates that after the peak of the X-ray event, the level decayed to class C2.8 at about 0320UT on 2/20/94. Edit the "Decay time, level=C2.8" text box to read "02/20/94 03:20".
- Click on the *Run Model* button to execute ISPM and the following figure will appear.



The results show that a shock will reach Earth at 11:09 UT on 02/21/94 with a dynamic pressure jump of 6.8×10^{-8} dynes/cm² after traveling for a period of 34 Hours and 01 minute. Ground magnetometer data show that a Sudden Impulse occurred at 09:01UT 02/21/94 indicative of the passage of a solar wind shock by the Earth. This is confirmed by solar wind data from the IMP8 spacecraft showing a shock passage with a dynamic pressure jump of about 1.6×10^{-7} dynes/cm². In this case ISPM predicted the shock arrival two hours late (a 6% error in overall propagation time) and a dynamic pressure jump smaller than observed by a factor of 2.4.

Run the STOA model and display text results,

- Scroll down the *Available Science Modules* list and click on *STOA*. A STOA object will be added to the *Active Science Modules* list, and a set of STOA Options will appear in the Environment Window.
- Under “Specify Event Duration” select the *X-ray Levels* option. We will use the same GOES 7 1-8 Angstrom X-ray data we used for the ISPM module. As in the ISPM case, enter the following data in the appropriate boxes so that the STOA program can compute event duration: “Event onset time” = “02/20/94 01:08”, “Flare lat (deg N)”=9, “Flare lon (deg W)”=2, “Type II speed (km/s)”= 1200, “Back. Class.”=B2.0 and “Peak Class.”=M4.0. Click in the “Decay time” text box (and label will change) and edit the “Decay time, level=C2.8” text box to read “02/20/94 03:20”.
- In the STOA model we have the option of entering a solar wind speed. Enter “Solar wind speed (km/s)” =400 to match the value used by default in the ISPM case. It should be noted that the real solar wind speed can be quite variable. On 02/20/94 the IMP-8 satellite recorded a solar wind speed which varied from about 580 km/s at 08:00 to about 500 km/s near the end of the day. Prior to 08:00 there was a data gap on that day. The next morning the solar wind speed had decreased to about 400 km/s by 01:00. Another data gap ensued, then the solar wind speed was 400 km/s from about 07:20 until the time of the observed shock at 09:00.
- On the left, under “Observer Location”, select the *Earth* option.
- Click on the *Run Model* button and the text window appearing will match the following figure.



The results in the previous figure show that a Mach 5.4 shock will reach Earth at 23:09 UT on 02/21/94, after traveling for a period of 46 hours and 01 minute. This is 14 hours and 08 minutes later than the observed shock described earlier, and exactly 12:00 hours later than the ISPM predicted time.

Run PPS and display text results,

- Click on *PPS* in the *Available Science Modules* list. A PPS object will be added to the *Active Science Modules* list and a set of PPS Options will appear in the Environment Window.
- Under “Specify Data Type”, select the *Radio* option and under “Specify Flux Type”, leave *Peak Flux* as the default flux type. Also leave the *Radio Frequency* button set at the default value of 2695 MHz. Since we are considering the same event as discussed above enter “Flare lat (deg N)”=9 and “Flare lon (deg W)”=2.
- The Palehula RISTN site observed a 2695 MHz fixed frequency radio emission event beginning at 0105UT on 2/20/94 and reaching a maximum at 0114UT with a duration of 85 minutes and a peak flux of 190 SFU. Edit the “Event onset time” text box to read “02/20/94 01:05”, set “Time of maximum”= “02/20/94 01:14”, and “Peak Radio emiss.: RAD26P(SFU)”=190.
- Click on the *Run Model* button to execute PPS. When complete a new window will appear giving the results in text format as shown in the figure on the next page.

PPS predicts that the > 10 MeV proton flux at the Earth, as measured by the GOES satellite, will exceed a threshold of 10 protons/(cm² s sr) for a period beginning at 10:00UT 02/20 and ending at 21:00UT 02/20/94 with a maximum flux of 18.3 ptns/(cm² s sr) at 10:01 02/20/94. The same flux threshold will be exceeded by the > 5 MeV flux beginning at 11:00UT 02/20/94 and ending at 07:00UT 02/21/94 with a maximum flux of 29.9 ptns/(cm² s sr) at 11:12 02/20/94. For the > 50 MeV protons the threshold is never reached and the maximum flux is 0.744 ptns/(cm² s sr) at 8:48 on 02/20/94. In this example we will not consider the user-specified quantities which are also displayed in the PPS output window. These include polar riometer absorption forecasts and maximum radiation dosages at specific altitudes, and are described in the manual pages for the PPS Science Module.

Examining the GOES-7 proton data for this interval it can be seen that the > 5 and > 10 MeV fluxes both exceed the threshold value at about 03:00UT 02/20/94. The first maximum of the > 5 MeV flux is reached at about 09:45UT 02/20/94 and has a value of about 220 protons/(cm² s sr). Likewise, the first maximum of the > 10 MeV flux is reached at about 06:00UT 02/20/94 and has a value of about 80 ptns/(cm² s sr). The maximum value of the > 50 MeV channel is reached at roughly 03:00UT and has a value of about 1.5 ptns/(cm² s sr). For this event, PPS does a reasonable job for the > 50 MeV fluxes and gets progressively worse for the lower energy channels, overestimating transit times and underestimating intensities. This event, however, turns out to be a fairly rare example of a ‘hybrid’ solar proton event. Besides the initial population of energetic protons generated by the energy release near the Sun (the population that PPS is built to model), there is another population of energetic protons reaching the Earth that is generated by the energetic interplanetary shock traveling towards the Earth (i.e., the shock that ISPM and STOA are modeling). Indeed, after the initial rise and a very small decay, the >5 and >10 MeV fluxes rise

again to reach a maximum of $4.e+4$ and $8.e+3$ ptns/(cm² s sr), respectively, at 09:00UT on 2/21/94. This is exactly when the interplanetary shock arrived at Earth. A combination of an unexpectedly strong shock with the correct propagation path towards Earth made this event one of the strongest solar proton events of solar cycle 22.

```

AF-GEOSpace: PPS Output

Admin

----- PPS - Proton Prediction System - Version '95 -----

Maximum day polar riometer absorption will be 1.64 db at 10:51 Feb 20
Maximum night polar riometer absorption will be 0.63 db at 12:22 Feb 20

70000 ft high flyer polar max dosage will be 0.0 mR/hr at 08:10 Feb 20
50000 ft high flyer polar max dosage will be 0.0 mR/hr at 08:07 Feb 20

E V A max. astronaut dosage will be 0.005 R/hr at 10:10 Feb 20
Inside [ 2 gm/(sqcm) ] max dosage will be 0.001 R/hr at 08:55 Feb 20

Protons: >10 MeV gt 10 Feb 20 10:00 to Feb 20 21:00; max flux of 1.83E+01 at 10:01 Feb 20
fluence of 1.11E+06
Protons: > 5 MeV gt 10 Feb 20 11:00 to Feb 21 07:00; max flux of 2.99E+01 at 11:12 Feb 20
fluence of 1.90E+06
Protons: >50 MeV gt 10 00 00:00 to 00 00:00; max flux of 7.44E-01 at 08:48 Feb 20
fluence of 4.65E+04

Input Parameters:

Input Type: RAD26PP

Date of onset: 02/20/94
Time of onset: 01:05
Time of maximum: 01:14

Event lat (deg N): 9.00
Event lon (deg W): 2.00
Event amplitude: 1.90E+02

Expert mode parameters:

Normalization energy channel: 0
Flux normalization value: 0
Time of flux maximum: 00/00 00:00

Slope of integral spectrum: 0.0
Slope of differential spectrum: 0.0

```

This completes the Example of The Energetic Solar Event of 20 February 1994.

Product Information

AF-GEOSpace was developed by the United States Air Force Research Laboratory.

Current members of the development team are:

- T. Hall and E. Holeman: Boston College
- M. Tautz, A. Ling, and G. Law: Radex, Inc.
- R. Hilmer, G. Ginet, K. Groves, R. Gauthier, K. Kadinsky-Cade, D. Brautigam: Air Force Research Laboratory

Former team members and consultants: R. Biasca, D. Anderson, S. Basu, G. Bishop, D. Bilitza, W. Borer, T. Bullet, R. Daniell, M. Dryer, M. S. Gussenhoven, M. Kendra, A. Long, J. Lopriore, A. Mazzella, W. McNeil, E. G. Mullen, F. Rich, D. Smart, M. Smitham, N. Tsyganenko, J. Wise.

To report program bugs, get technical help, or obtain a copy of AF-GEOSpace, please contact Robert Hilmer at 781-377-3211 (DSN 478-3211) or email: *Robert.Hilmer@Hanscom.af.mil*. Comments on AF-GEOSpace's capabilities and suggestions for future versions are appreciated.

AF-GEOSpace software may not be re-distributed without written permission from the Air Force Research Laboratory.